AN

ESSAY

ON THE

CONNECTION

BETWEEN

THE ACTION OF

THE HEART AND ARTERIES,

AND THE

FUNCTIONS OF THE NERVOUS SYSTEM,

AND PARTICULARLY

ITS INFLUENCE IN EXCITING THE INVOLUNTARY ACT

OF

RESPIRATION.

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PREFACE.

VARIOUS have been the opinions respecting the cause of the involuntary act of respiration, but these have hitherto failed of proving satisfactory to the unbiassed physiologist. In the following pages I have stated my own opinions with very considerable hesitation, but as the great secrets of nature are seldom to be revealed but by the succeeding labours of different individuals, so I have contributed, what appeared to me sufficiently important for extending our knowledge, not only

on this interesting subject, but on various points connected with it.

It is difficult to be at the same time concise and clear, and therefore it is difficult in an Essay to touch upon important subjects connected with the main object, and not to acquire an appearance of negligence. I feel it necessary to make this apology, although I have not hastily written this short work.

6, *Tavistock Square*,
May 22, 1829.

AN

ESSAY, &c.

Mr. Hunter* says, "Life I believe to exist in every part of an animal body, and to render it susceptible of impressions which excite action; there is no part which has not more or less of this principle, and consequently no part which does not act according to the nature of the principle itself, and the impressions thence arising, producing thereby infinite variety both in all natural and diseased acts."

Muscles have a power of contraction in themselves, which may be termed their irritability, or their life, and although these are generally called into regular action by connexions with the nerves and brain, and spinal marrow, or the

* Treatise on the Blood, &c., p. 3.

motion imparted to the nerves by the sanguiferous system, the actions of some of them are in a considerable degree independent of these attachments.

The fœtus in utero moves before the brain and spinal marrow have acquired any sort of perfection of structure; monsters move also, where there is a deficiency of the brain; and some vegetables have a similar power of contraction, which, however, seems to be directed by external agents, and is in some degree like that in the muscles of animals after their nerves have been divided.

It has been observed, that the heart is a beating point in the rudiments of the chick on the fourth day of incubation, and at this time no other parts are particularly developed. The cause of it begins with the application of heat to an egg, which has been impregnated and is endowed with the living principle. This beating point is a phenomenon to be ascribed to one of the laws imparted by the Creator, and for which it is impossible to account by any reasoning. What takes place thus in the egg, takes place also in the uterus

of viviparous animals. As the law of nature commands this first action, so it is ordained that it should commence at different times in different animals. In the evolution of the fœtus other parts become gradually developed, and then the heart begins to assume its peculiar office of circulating the materials for modelling the various organs, and bringing them to that state of perfection which is required at their change of existence. At birth the heart is the fountain of the new life, for it first incites to action the parts whose functions are absolutely required for this new state of being.

The great inherent irritability of the heart is not to be attributed to a more complicated distribution of the nerves; and as nature never designed a great multiplicity of agents for accomplishing a purpose for which a few would suffice, it is impossible to view accurately the intricate and elaborate arrangement of its nerves in man without a full conviction that this is unnecessary for its own action. The formation of its nerves, in most animals, is very simple, and shows that this

does not exist in man for giving it power only, but very much for associating its actions with a more complicated assemblage of parts than is necessary for the perfection of its functions, as the propelling power of the blood. In animals the heart has the same task to perform as in man, and why, therefore, is there not the same distribution of nerves? This difference plainly demonstrates that all the nerves in man are not required for its action alone. In none of the mammalia have I found the same extensive communications: in birds the nerves are still more simple, and in some of the inferior animals are with difficulty demonstrated.

The heart in man is supplied by the par vagum and grand sympathetic, and the branches going to this organ have many very intricate communications with ramifications of nerves terminating on various parts, with which the heart thus becomes particularly connected. The trunk of the par vagum and grand sympathetic are united in many animals throughout the whole neck, and may thus be assimilated sufficiently for the functions of

the organs they supply, but not for associating them with other parts.

Although the great inherent irritability of the heart may give it the appearance of spontaneous motion, it, nevertheless, in man and many animals, stimulates its own nerves by its action, and thus, in some degree, ministers to its own support; but it cannot even thus be kept in motion long, for when the lungs have become passive, its action stops sooner or later: if the animal be decapitated, and artificial respiration produced, its action is restored, and continued so long as respiration is performed.

Artificial respiration shows that the action of the heart is in a great degree independent of the nervous system, and that the muscles of respiration are of a very different nature from the muscular substance of the heart, and are irritable in a different manner. The powers of the nerves are so depressed by some poisons, that although they be agitated by the heart and blood-vessels, they cannot afford the necessary stimulus to the parts they supply; but when the influence of the

poison has been dissipated, their functions may sometimes be restored, provided artificial respiration be kept up so as to maintain sufficiently the action of the heart.

Some poisons arrest the action of the heart instantly, whilst others put a stop to the functions of other muscles; and these circumstances afford additional confirmation of the opinions, that a great difference exists either in the nature of different muscles, or the nervous powers which influence them.

1828. October 2d. I gave a young dog some Hydrocyanic acid; it appeared dead in about two minutes; it however began to breathe again, and did so irregularly for about two minutes longer, when a convulsion came on, and it breathed no more. I then opened the chest and found the heart pulsating strongly, and both the auricles and ventricles continued to beat more and more slowly for two hours. About a quarter of an hour after the acid was given, I pinched the phrenic nerves, and the diaphragm contracted immediately, as did also the fore leg when I irritated the axillary plexus. The peristaltic

motion of the intestines continued above an hour, and whilst there was no pulsation of the aorta. It appears that the power of the nerves was only diminished, but not destroyed, by the poison, as the diaphragm and other muscles were roused to action by the severe stimulus of pinching their nerves. Although the principal effect of this poison is a suspension of the functions of the brain, yet the nerves themselves suffer, only in a less degree.

A calf about a week old, could not be destroyed by as much of the same Hydrocyanic acid as killed an ass a year old. It appeared senseless, but kept respiring at very long intervals; and was only killed by the assistance of strangulation. The superior part of the animal was afterwards injected by the abdominal aorta, and the veins were thus filled as well as the arteries. I presume the inherent irritability of the heart, and also the fœtal communications, allowed its action to continue until the effects of the acid became partly dissipated. Similar effects may be produced by a blow on the occiput, or any severe injury to the brain.

I have premised these observations in order to show that the action of the heart at first is not to be ascribed to any power communicated from the parts with which it is connected, although it be afterwards dependent on its association with other organs, and more particularly in animals with warm blood; for in some which belong to a lower scale, as the frog, carp, &c., it may be removed, and its action continue; and in some young animals with warm blood, the same inherent power may be more easily demonstrated; and it has even in executed subjects continued to pulsate a considerable time after apparent death had been produced. After tying the principal arteries of a puppy, I removed the heart and lungs, and placed them on a table exposed to the air, and the heart continued to pulsate for several days. The resemblance of its internal structure to that of the amphibia, which has at this period hardly ceased to exist, may in some measure account for this same spontaneous motion.

I do not wish to inculcate that nerves are not required for the functions of the heart.

As it is an organ connected in action with almost every portion of the body, it is necessary on this account alone, that it should receive nerves for associating its operations with those of every other part, that the necessities of the whole may be regularly and sufficiently supplied.

I have previously stated, that there is inherent in every muscle, the living power, termed its irritability; and also the superadded one, termed the nervous; and I believe that these are distinct, and exist in different degrees according to the structure and uses of the muscles: and although after the fœtal state has ceased, these cannot act independently of each other very long, yet I conceive in many animals death would much more frequently occur, had not the heart some independent power. And if the different organs which compose the body had not been separately formed during the fœtal state, they must have made an equal progress during their growth, and the heart could not then have possessed that prominent action and almost perfection, before the for-

mation of many other parts, which are of equal importance for the well-being of the body after birth. I cannot help concluding, that there is a considerable difference in the nature of muscles themselves, as well as in the nerves distributed to them, and that their peculiarity of action arises from different combinations of these different qualities. In various animals the muscles have various degrees of irritability, as is perhaps strikingly illustrated in the eel, as well as by the heart, and intestines of different animals.

The functions of many organs are dependent on the motion communicated through the heart by the arteries to their nerves, which in man, and some animals, thus becomes the principal origin and support of the most complicated and important operations of many parts and particularly of the brain and nervous system.

Before the nerves reach the heart, they encircle its large vessels in a very curious manner; but the arteries themselves, throughout the body, receive a very considerable supply of nerves for their own peculiar uses. And if

we had no other evidence of the distribution of nerves to the arteries, than is manifested on using a ligature, we must be convinced that they are not unimportant: when, therefore, we are able to observe how numerous they are, and what care is taken to supply them from different sources, we cannot hesitate to conclude that the arteries themselves perform very important functions, and are not mere tubes subservient to the action of the heart, for the purpose of conveying the blood over the body entirely by its power of propulsion.

It has been supposed that the blood-vessels are furnished with nerves almost entirely by the grand sympathetic; but this is not the fact, for although the aorta be supplied by it, many of the arteries on the contrary receive contributions from other sources, and frequently from the nearest branches, and thus their actions become more readily associated with the actions of the parts the branches themselves are distributed to. It is thus that the supply of blood is regulated in the different organs, for it would be impossible for the heart to effect more than to circulate it

over the system generally; the connexion, therefore, of the actions of the arteries with those of the heart, and at the same time an allowance of actions in some degree independent of those of the heart, would in no manner be so well effected as by connecting, according to their exigencies, the arteries of the different organs with their respective nerves, and at the same time with those of the heart, by means of the grand sympathetic nerves. Thus we see how wonderfully nature has contrived the animal body, to have been enabled to unite in each organ so many complicated structures, and to produce their intended effects with so much facility.

That the nerves have considerable power over the arteries independently of the heart, we have the opportunity of witnessing in diseases. I have known a patient complain of numbness on the left side, which was at the same time attended with coldness, and a slightly diminished muscular action; the pulse was weaker and not according with the pulsations of the right side, the latter being perfectly free and natural; there was no organic

disease, for the symptoms went off and returned several times within a few days.

A part may be supplied with nerves from different sources, but it is usually supplied from two. In the latter arrangement, there is a nerve proportionate with the size of the artery, by the side of which it passes, and both the nerve and artery divide into branches, to terminate in the organ for which they are destined; and there is a second nerve which is very small in proportion with the first; this adheres to the artery, and is more or less intimately connected with its structure. As the nerve adhering to the artery has generally a very extensive connexion with nerves from different sources, for the perfect completion of its healthy functions; so, in disease there may be irritation depending on the nerves of the part itself, and also on that which adheres to its arteries; and although the source of the latter be at a distance, it may nevertheless manifest itself more particularly in what appears to be a local disease; and if experience had not confirmed the necessity of both local and general

remedies at the same time, anatomical investigations might have suggested it.

When the par vagum has been divided, there is an increased quantity of mucus in the trachea, and as no nerves are given to the trachea from any other source, the secretion must be performed by the arteries, and the nerves, which are distributed to them, unless it be presumed that the communications between the superior and inferior laryngeal nerves, can have any influence in promoting it. The nerves which accompany the arteries of the larynx and trachea, are principally from the grand sympathetic. When the medulla spinalis is compressed, the mucus of the bladder is secreted in an increased quantity, but this is not more remarkable than that the secretion of the kidneys should go on under the same circumstances; but this, nevertheless, shews that the nerves, which accompany the arteries themselves, are the agents, as the nerves of the bladder are deprived of any direct communication with the brain, through the spinal nerves. If the medulla spinalis be so compressed that it can-

not keep up a proper connexion with the brain, has that part below the injury the power of imparting any sort of vigour to the nerves, which are connected with it? Secretion and reparation go on in a limb, whose nerves have been divided, and therefore the nerves of the arteries themselves, from their connexions with the grand sympathetic, may give them the power of secreting. The branches of the grand sympathetic which accompany the spermatic arteries, are those on which the secretion of the testis entirely depends. Some physiologists have thought that secretion can go on without the influence of the nerves, but I think it may be doubted whether those minute filaments which adhere to the arteries, may not have escaped their observation, and have promoted the secretion, although less powerfully than before.

When the functions of any organ, and especially when its connection with the nervous system, is to be considered, it becomes necessary to be acquainted with the relation it has to the brain, the spinal marrow, and the grand sympathetic. I shall

therefore take such notice of the structure and functions of these important parts, as is consistent with the object of my present inquiry.

By examining the intimate structure of the brain, we see it formed into parts of various shapes; but from these peculiar configurations we have been enabled to draw but few, or just, conclusions. It is most plentifully supplied with blood, so much so, indeed, as to receive a much greater quantity than any other part. It is supposed that something is secreted by it, but whether it be so, or what it is, is unknown. It is difficult to consider the whole brain as a secreting organ; but the acquisition of power throughout the body, by proper rest, favours the opinion, that only a certain quantity of nervous influence is formed in a given space; that it accumulates during rest, and is expended by exertion; but if it could be thus formed and collected, we might suppose that a suspension of the supply of blood would be borne for a short time; but it is not so, except in a very limited degree. An accumulation of

nervous influence is also supposed to take place during rest, as exertion can only be maintained a certain time, and if it be continued longer, exhaustion is produced, and can only be prevented or compensated for by an increased supply of food, some stimulating drink, or some narcotic drug. But it may be urged in reply, that the heart flags, and ceases to maintain sufficiently the motion of the brain, as too much fatigue produces uneasiness about the heart; and we know that stimuli and narcotics can allay this, but we have no proof that these favour any secretion from the brain, because they allow a continuance of exertion. As the brain itself is exercised, its fibrous structure may require rest as well as that of the muscles. There can be no doubt but that the functions of the brain are modified by the disposition of the parts, as in its configurations and the connexion and direction of its fibres. These are so placed as to be distended in different degrees by the blood, and stimulated by its motion, and may produce various actions,

in some way resembling the difference required for the pipes of the organ, or strings of other musical instruments. Peculiar qualities may be thus also afforded to the nerves, which also vary in their formation for different purposes. That the functions of the brain and nerves are promoted in this manner, may be presumed from the necessity of a mechanical apparatus for the production of the senses, and from the exquisiteness of the latter depending on the perfection of the former.

The brain and nerves form one continued chain; but the latter cannot produce any decided effect without a connexion with the former; and we must not suppose that these are mere conductors of nervous influence, as may be inferred from the disproportion between the brain and nerves in man and animals, from the nerves corresponding with the size of the animal, and not with that of the brain; and it would be difficult to suppose that larger nerves are necessary to convey a smaller quantity of nervous influence, as we must presume that this would correspond

with the size of the brain and the supply of blood, and both of these are less in quantity in an ox than in man. Neither the spinal marrow nor the nerves can produce sensation without a communication with the brain, and we must therefore conclude that there is a difference in the conformation of the parts, in the disposition of the fibres, &c., which makes the difference between them and the brain. I cannot think that the functions of the brain and nerves are entirely performed by means of a secretion. There is no doubt but that some peculiar spirit is inherent in the brain and nerves, which is formed with them, and is their life; but that the capabilities of the parts for producing different effects depends on their configuration, principally modified by the action of the blood-vessels. Some may be inclined to believe that there must be a nervous influence, as the result of a chemical process, because so large a supply of oxygenised blood is required; but the muscles are also freely supplied with the same blood, and it is not proved that any thing is im-

parted to them by it, except vitality, and so it is with many other parts of the body.

I shall make a few observations on the structure and functions of the medulla spinalis, before I proceed any further respecting the brain.

The medulla spinalis is a continuation of the medulla oblongata. It begins just below the origin of the ninth pair of nerves, and in the adult terminates in a point at the second lumbar vertebra. Its size varies in different parts according to the quantity of nerves given off from it. It is composed of two parts which have a different appearance, the one is white and termed medullary; the other is of a reddish colour, and usually termed cineritious. It is chiefly formed of the white part, which is firmer than the cineritious. It is divided into two lateral portions, by a middle line on its anterior and posterior surfaces. A separation is very easily made at the line on the anterior surface, but on the posterior it is effected with much more difficulty; but when it has been carefully made at

the line on the posterior surface, small threads may be seen crossing from one side to the other. When a separation has been made at each middle line, the two lateral portions are found to be only united by a small slip of the cineritious substance, which extends nearly across the medulla; from this slip a small portion of the cineritious substance on each side is directed obliquely forwards, but a much larger portion goes, likewise, from each corner obliquely backwards; and in this latter part a longitudinal space is formed, into which the pia mater seems to enter, by perforations for supplying it with blood-vessels.

The medulla is composed of cells, in which the medullary and cineritious matter are deposited. The cells are attached to the pia mater, and may be well compared with the cancelli of bone originating from the more firm external shell.

Four sets of nerves arise from the medulla, viz., two anterior and two posterior. In observing their origins superficially, it would seem that each fasciculus arises immediately by a number of minute threads, and each of

these has its origin by several others, which appear to be a continuation of the cellular structure just mentioned. In examining each surface of the spinal marrow, it will be found that the minute threads arising from them sometimes communicate, so as to unite the bundles of two separate nerves; but this takes place without any decided regularity, and by far the greatest number of the nerves is entirely separate. I examined the spinal marrow also in some animals, and it afforded similar appearances.

Immediately on leaving the spinal canal, each posterior fasciculus terminates in a ganglion, which appears to be composed chiefly of the fibrillæ of the posterior bundle of nerves, and a reddish substance of the same nature as the neurilema. When the fasciculus reaches the ganglion, each fibrilla spreads out into finer ones in its substance, and these, after having communicated very much with each other, collect again, and form a nerve, to which the anterior fasciculus becomes immediately united. The nerve thus formed is much larger than both the fasciculi added together before the formation of

the ganglion, and it is also much stronger from its being enclosed in a thicker covering, called the neurilema.

When the medulla spinalis has been sufficiently immersed in alcohol, on each side its middle line, both anteriorly and posteriorly, it is easy to observe a slip of medulla, which is composed of longitudinal fibres, extending from its termination to its connexion with the superior part of the medulla oblongata : this slip has a direct line of separation from the part which gives origin to the nerves, but it is nevertheless connected with it by communicating fibres.

On the anterior part of the medulla, the longitudinal fibres appear to be principally the continuation of the corpora pyramidalia.

On the posterior part there is the same appearance of longitudinal fibres, which on each side of the median line form two portions; these, at the medulla oblongata, wind round, as if to terminate in the exterior edge of the corpora restiformia, and at the cauda equina become very slender. These prolongations communicate freely with the other parts of the medulla. The spinal marrow may there-

fore be said to consist of cerebral and spinal parts; the latter, on the anterior surface, begin at the inferior extremity of the corpora olivaria, by a very acute angle, and on the posterior, by a more obtuse angle near the lowest part of the corpora restiformia, and on each side, between these two spinal parts, there is another, or middle portion, whose fibres spread towards the anterior edge of the corpus restiforme: this disposition appears to be formed for making distinct separations between different parts of the medulla oblongata, and the medulla spinalis.

I think it not improbable that the cineritious part and the lateral portions form the spinal marrow, strictly speaking, as a distinct organ, and also give origin to its nerves; and, that the anterior and posterior bundles of longitudinal fibres, form its cerebral portions, which exist for uniting every part of it properly with the brain. Without this structure, it is difficult to conceive how each nerve is connected with the brain, so as to perform distinct and separate functions, and I conceive there is a regular communication by these fibres, in a way similar

to what takes place between a nerve of the brain, and the part it is distributed to. On the anterior part, the longitudinal furrow which separates the two halves, is much deeper than on the posterior part, and this probably makes them more distinct, a quality necessary for the performance of the functions of the several muscles of the two sides of the body. On the posterior part, the longitudinal furrow may be traced in some degree, but it is not distinct, and cannot be properly made without dividing the medullary matter itself. It may be said, these longitudinal fibres associate in action all the nerves; but such an arrangement would, I conceive, produce too much connection between the various parts supplied by them, and consequently confusion; they very properly connect each part of the spinal marrow with the brain, but the junctions of the nerves, after they have left the spine, associate the different organs, a plan beautifully calculated for producing limited and independent actions.

When the spinal marrow is divided, all sensation and voluntary motion, excited through the nerves arising from the part below the

division, ceases; or, when a nerve only is divided, the same impediments to the usual functions of the nerve are also produced. From these circumstances alone we should conclude that there is a decided communication between each portion of the spinal marrow and the brain, and then between the latter and each nerve. If the component parts of the spinal marrow and brain be the same, it must be supposed that the different functions arise from the different configuration, or disposition of its substance; or if it be maintained that the functions of both these parts are effected by the production of a nervous influence, it must likewise be concluded, that it is of a different nature in each of them. I believe, therefore, that the difference is in the different disposition of the particles, or matter, of which each of these is composed.

In examinations of the nervous system, we see many of the nerves to vary from each other at their origins, and not only in their mode of connexion with the brain, but also in their structure. They have for the most part different functions to perform, and it is

reasonable, therefore, that they should differ from each other in structure. Although this diversity may in some degree account for the different uses of each nerve, it nevertheless must be acknowledged, that these depend also on the different conformation of the portions of brain from which the nerves arise, and perhaps, also, in a very material degree on their connexions with the blood-vessels, and the structure of the organs on which they are finally distributed. It cannot, therefore, be denied, that the nerves in their most essential points owe their powers to their origin from the brain, or the parts of the brain with which this is connected, as is proved by the destruction of the portio dura, which would interfere very little with the functions of the parts of the face to which its branches are distributed, as the communication with the fifth would then be sufficient for imparting the nervous energy, or whatever passes by the nerves, if a mere communication with the brain were only required. Therefore, if attempts are to be made for gaining any decisive knowledge respecting the nervous sys-

tem, they must be so directed that the whole may be properly considered. If every action be ascribed to the power or agency of the brain, and the nerves considered as parts of very inferior importance, or if the study of the brain be neglected, and the various actions produced by the different organs of the body be accounted for entirely from their connexions with the nerves, no satisfactory knowledge can be acquired. The brain, indeed, is very curious, but is of itself an almost useless structure; for when any of the nerves have been deficient at birth, or the organs which minister to their uses have been imperfect, man has proved very little superior to the lowest animals.

Although the brain is the seat of mental acquirements, and directs the various operations of many organs concerned in the production of complicated actions, I consider that an exterior system was also necessary for producing an association of sensations and actions in the various parts of the body. I believe each nerve has a distinct origin in the brain, and for the purpose of associating the different

parts necessary for harmonious sensations, there is a distinct communication between the different nerves concerned in their production. The functions of the brain become modified by the impressions it has been continually receiving from the exterior system; and if it were not so, it would remain unimproved from its original state, as has been the case in entirely uneducated children, or those whose organs of the different senses have been deficient at birth. There is a power in the brain which first incites to action, and is more or less extensive, and no doubt varies with its structure in different animals; the parts acted upon convey the image to the brain, which sooner or later receives impressions sufficiently strong to produce memory, and then by association, judgment. When the memory has completed any purpose, slight trials can put the exterior system in action, and then it is that the mind and body so particularly sympathize. It is necessary, therefore, in attempting to account for sympathies, &c., to learn whether they have not originated externally; for although it be reasonable to suppose, that

the nerves arising from the same track or part of the brain, may perform almost similar functions, because we observe this so uniformly throughout the whole, or the greatest part of the spinal marrow, we nevertheless must not conclude that all these nerves are therefore connected in action, and that sympathies between them take place in the brain, independently of the organs to which the nerves are distributed; for if the nerves were thus sufficiently connected in the brain, there would not have needed so many intricate junctions, between themselves and the blood-vessels, and such care for their security, as we observe throughout the body. As, therefore, all the comforts and attainments of man, depend on the perfection of the nerves as much as on the brain, every exertion should be made for searching out their intricacies, discovering their uses, and then for trying to correct their faults. Very few diseases are originally seated in the brain and spinal marrow; but these suffer chiefly from a connexion with other parts.

These observations apply principally to the cerebral and spinal nerves, as continuations of

the brain and spinal marrow. I shall in some of the following pages speak of the other functions of the nerves, as arising more particularly from their connexions with the grand sympathetic, and the heart and blood vessels.

There are three conditions necessary for the functions of the brain :—Its motions; its receiving blood sufficiently oxygenised; the integrity of its own substance, and particularly as to its chemical properties.

I shall first inquire respecting its motion; and this leads me to observe, that the branches of the internal carotid and vertebral arteries are disposed in their peculiar manner for affording a stimulus to particular parts of the brain, and some of the nerves going off from it.

The pulsations of the brain are said to arise from two causes, viz. the action of the arteries, and respiration. As these are synchronous with those of the heart, it is most reasonable to conclude that these are imparted through the arteries. The pulsations are going on perpetually, and so long as these continue moderate, the functions of the brain are in every respect

properly performed,* Richerand has endeavoured to prove, and I think successfully, that the pulsations are produced by the heart and arteries. "I laid bare the brain in a rabbit, and then tied the trunk of the ascending aorta: the moment the blood ceased rising to the head, the brain ceased moving, and the animal died."

The motion of the brain has been attributed to respiration; its falling to inspiration; and its rising or beating to expiration. The number of times respiration is performed in a minute, is much fewer than the pulsations of the brain; but, nevertheless, there may be a greater difference in their force during expiration.

During expiration the blood is delayed in the right cavities of the heart, so that the jugular veins remain distended, and also the sinuses of the head, and has been thus supposed to produce the motion of the brain; but if this were the case, a very considerable succussion must be communicated to the blood in the longitudinal sinus, as it must be through

* Elements of Physiology, translated by Dr. de Lys, p. 344.

this that the impulse would be given to the brain.* M. Lassus says, that the most careful and multiplied experiments have taught us, that the veins of the dura mater and brain, which empty themselves into the sinus, are not susceptible of the movements of dilatation and contraction, and have no pulsation. If they be opened, the blood does not pass out in jets, as from an artery.

Richerand* says, "I have injected the internal jugular veins. The cerebral mass remained motionless." Again, "The tying of the internal jugular veins did not stop the motions of the brain; but its veins dilated, and its surface, bared by the removal of a flap of the dura mater, was sensibly redder than in the natural state. The dog became affected with stupor, and expired in convulsions. The opening of these veins did not hinder the continuance of the motions; they grew fainter only when the animal was weak-

* Mémoires de l'Académie Royale de Chirurgie, tom. v. p. 55.

† Elements of Physiology, translated by Dr. de Lys, p. 344, 345.

ened by loss of blood." Again, "The opening of the superior longitudinal sinus did not weaken the motions of the brain. It is observed the blood flows out more freely from it during the elevation."

It will be necessary to inquire whether the pulsations exist as a natural consequence of the formation of the brain of man and some animals, and whether they be necessary for the performance of its functions. I am inclined to believe that the functions of the brain, in different animals, require a peculiarity in the supply of blood; and, therefore, we have the rete mirabile, or some other variety, in the size and distribution of the arteries.

Bichat* considers the functions of the brain to be very greatly dependent on the action of the heart; and, in making experiments, he says: "Expose part of the brain, so that you can observe its motion; then tie the carotids. Sometimes the motion of the brain becomes feeble, and then the animal is senseless; at other times it is as usual, the ver-

* Sur la Vie et la Mort, p. 157.

tebral arteries making up exactly for those tied, and then none of the principal functions are deranged. There is always a correspondence between the vital energy, and the rising and falling of the brain." Again, "If a portion of the skull be removed, and the course of the blood intercepted in all the vessels leading to the head, the motion of the brain ceases, and life is destroyed."

Bichat also says, that compression of the brain from accident prevents the proper degree of motion, and thus produces its symptoms; but it is difficult to determine this point precisely. Books of surgery abound with cases in which depressions of the skull have continued permanent, without any signs of oppressed brain; and also with others, in which the peculiar symptoms were relieved by a removal of the pressure. The bad effects are not produced from injury to the part of the brain in contact with the depressed bone, for the brain may be wounded, and a considerable portion removed, without any impediment to its functions, either at the time or afterwards. Nevertheless, the

pressure sometimes appears so slight, but accompanied with such violent symptoms, as almost to render nugatory any reasoning on the subject. Hernia of the brain does not, of itself, appear to interfere with the functions of the organ ; but if pressure be made on the hernia, pain in the head and other symptoms arise, which are plainly owing to an interference with the free motion of the brain, and not to any effect on the hernia itself.

Adhesions between the membranes, by preventing the free motion of the brain, may impair the intellectual powers; and an inflammatory state of the arachnoid membrane, or its consequences, may make the pulsations borne with much inconvenience. In the following case, the diseased appearances of the arachnoid membrane lining the dura mater, corresponded exactly with those on the surface which covered the convolutions, and there were also many adhesions between them; and these, I conceive, prevented the free motion of the brain, and produced the cloudiness of the mental faculties; and, on

any exertion of the mind, when the circulation was quickened, caused such irritation, as disturbed the ordinary action of the brain.

CASE.

A GENTLEMAN, 36 years of age, had been subject to epileptic fits about two years. He fell on his head from a considerable height, when a boy, and, in consequence, had much disturbance in this part; but no decisive measures were taken for its removal. Ever since he became troubled with the fits, his mental faculties have been impaired, and most particularly his memory. For their removal he lived abstemiously, was occasionally bled with leeches, and, when the brain was particularly oppressed, venesection was performed; and he took at different times small doses of blue pill and aperient medicines. He had frequent sensations, which would almost amount to fainting, for a minute or two; but, latterly, these had very much diminished. The last bad fit was in last May. He had lately been much disturbed about the illness and death of a

friend, and whose last symptoms were those of typhus fever. He visited him during his illness, and also saw the dead body; and the following day, which was March 6th, 1828, about 8 A. M., he was taken with a severe rigor. He said he was not cold, but his feet were so when I felt them. He complained of his head; his pulse was weak and irregular. His legs were put into hot water, and he appeared better. He took four grains of submuriate of mercury, and some aperient medicine. At 4 P. M., he was feverish, his pulse 100, and strong, and he complained much of his head; he was very drowsy. A vein was opened, and 12 ounces of blood passed freely out, when he became very faint. After the blood had stood some hours, there was a large proportion of serum, and the crassamentum was very loose. He said his head was easier after the bleeding, and it continued so in the evening, but he was still very sleepy. —7th, at 8 A. M. He had slept all night, and was roused with difficulty, and almost immediately relapsed into sleep. He had been copiously purged. There was some

erysipelatous inflammation about the part where he had a seton. The comatose state remained, and he died about 11 P.M.

EXAMINATION.

THIS was made on the 8th, at half-past 10 A.M.

There was a roughness on the inner table of the skull, at the back of the head, near the transverse ridge of the occipital bone. The external surface of the dura mater was very vascular, and, on dividing it, purulent matter passed out freely from over each hemisphere; it was thin, and contained flakes of lymph, and very much resembled the usual contents of a psoas abscess. The tunica arachnoidea, spread over the inner surface of the dura mater, was thickened, and covered with lymph, and, in some places, there were spots resembling ulcers. There was the same general appearance over the hemispheres, except that of ulceration; the pia mater was also thickened; there were many adhesions

between the two surfaces, so that, through these, the pia mater was united to the dura mater, and therefore could not allow free motion There was very little alteration from the healthy appearance in any of the membranes at the base: the substance of the whole brain was healthy. A small quantity of clear fluid, such as is seen in health, was found in each lateral ventricle; but in the most posterior corner of each of these cavities there was a hydatid, rather larger than a horse-bean, connected with the choroid plexus. If there was any change in the membrane lining the ventricles, and that forming the velum interpositum, it was a slightly-increased opacity; and the same might be said of the tunica arachnoidea at the base, and in the superior part of the spinal canal.

A difference in the number of pulsations of the brain is observed as the effect of irritation; and although it be difficult to draw any decisive inferences from this circumstance, yet it must be acknowledged that it makes a regular adaptation of this power appear of very great importance in promoting the func-

tions of the organ. In a case of injury of the head, Sir Astley Cooper* says, "I observed a circumstance in this young gentleman after his cure, which shows the influence of mental excitement in agitating the brain, and increasing, upon the instant, the quickness of its action. Something passed in conversation which displeased him, and his brain, which could be distinctly seen beating through the opening in his skull, immediately quickened from 80 to 120 in the minute. Struck with this appearance, I watched it for a few minutes, and, as his mind became calm, the pulsations gradually sunk again to about 80."

The brain requires a proper supply of blood for the performance of its functions; for when a great quantity is abstracted, its powers become almost annihilated, and a state of faintness is induced. Other organs also suffer, and the action of the heart becomes feeble, and the process of respiration partakes of the same languor. It must, therefore, be doubted whether the brain suffers most from

* Surgical Lectures, vol. i. p. 323.

the want of blood, or the action that is imparted by its motion. But the motion, and at the same time a copious supply, cannot of themselves maintain its action; but it is necessary that the blood should be sufficiently oxygenised. It is no unusual occurrence for people to die, and the structure and appearance of the brain and every other organ to be healthy, and the only deviation to consist in the presence of black blood in the arteries. It is difficult to say what degree of deterioration of the blood prevents the functions of the brain, as it may have the venous character, and yet support life for a short time. Mr. Hunter* says, "I bled a gentleman in the temporal artery while in a fit of apoplexy; the blood was as dark as venal blood." But it was not sufficiently deteriorated to extingush life, for he goes on to state that the patient was somewhat relieved. In the next case he had opened the temporal artery, and says, "But I observed that when she breathed freely, the blood from

* Treatise on the Blood, p. 55.

the artery became red; and when her breathing was difficult, or when she hardly breathed at all, the blood became dark; and this alternately several times in the course of the bleeding."

That it is the state of the blood which frequently puts a stop to the functions of the brain has, I think, been most clearly proved by experiments. Mr. Brodie* hanged a dog, and, as soon as it had become insensible, the trachea was opened below the ligature, upon which it breathed, and its sensibility returned.

The brain and lungs appear to be dependent on each other, and have their states mutually modified in different classes of animals. Thus, in the mammalia and birds, there is a completely double circulation. In the amphibia and fishes the blood is not changed in the same complete manner; and there is not only a more languid state of the functions of the brain, but of all the other parts of the body, and a greater de-

* Paris and Fonblanque's Medical Jurisprudence, vol. ii. p. 43.

gree in the amphibia than the fishes. If some animals require the blood to be more completely oxygenised, for the performance of the functions of the brain, most of the other organs must have it nearly in the same state; and this is only what would be supposed to take place in a being which requires a consent of all its parts for its perfection and enjoyment; for as each species must be governed by particular laws, it is necessary that every part should be obedient to them; and it is, therefore, difficult to conceive that any very material difference could exist in the quality of the blood necessary for the general use of all the organs. I have said it is requisite for all the parts of an animal, according to its natural scale in existence, to correspond with each other. Thus the structure of the heart of the amphibia, when transferred to the mammalia, not only produces the same languid state of the functions of the body, and a great degree of coldness, but also a distressing uneasiness on account of the disproportionate and different structures which are thus asso-

ciated with them, as is particularly illustrated by blue children.

I have said it is necessary the structure of the brain should be perfect. Tumours pressing on particular parts, or the removal of certain portions of it, impair, more or less, some of its functions. Poisons, as the essential oil of almonds, the juice of aconite, &c., destroy its functions; but what there is in these, which counteracts the cerebral powers, is I believe not known.

In the preceding pages, I have stated that three conditions are necessary for the functions of the brain; viz. motion, a sufficient supply of properly oxygenised blood, &c., and the integrity of its structure, and particularly as to its chemical properties. I shall now inquire whether these three states are not also necessary for the functions of the nerves.

It seems to have been one of the principal cares of the Creator, in the formation of the nervous system, to have placed many of the nerves, so that they may be stimulated by the parts they either pass over or are

destined to supply. In many animals, the action of the heart and blood-vessels principally performs this office; and in the inferior orders, whose circulation is carried on with a much less degree of power, we find the most important parts of the nervous system situated about the œsophagus, or some other part, which is best adapted for giving it a due degree of excitement.

Many of the arteries are surrounded by loose cellular membrane, so that their pulsations have not much influence on the parts about them; and, as some of the nerves are very loosely connected with them, I conceive that they are not, in a general way, very materially influenced by such approximation. When the carotid artery has been tied, the functions of the par vagum do not appear to have suffered; but the situation of some of the nerves with the arteries, nevertheless, effects very important purposes.

As the functions of some nerves require to be performed occasionally, and others constantly, so we find a very different distribution of the nerves. When parts are wanted to be in continual action, their nerves are so con-

nected with the heart or the arterial trunks, as to be perpetually stimulated by them; but when occasional action is only necessary, then they are connected with parts which are occasionally exciting them, as must be the case with the branches of the par vagum encircling the œsophagus, the nerves of the bladder, and other parts. And when the will excites muscles, we do not find them, in the first impulse, contracting with their perfect energy, but, in a short time, the nerves become stimulated by the motion, and then they act with full force. I conceive, the nerves are so connected with the muscles, that, in the motion of the limbs, the set of muscles in action stimulates those which are to succeed, by putting on the stretch, or elongating to a certain extent, the nerves which supply them; and thus the alternate action tends to stimulate the muscles alternately, and produces the regularity and efficiency of their movements. The distension of the bladder and rectum irritates their nerves to produce contraction, and very much by their being stretched; and many other examples might be adduced.

* In a case of compound fracture of the tibia and fibula, in which the upper portion of the tibia projected through the wound, and could not by any means be kept in a proper position, so that amputation became necessary. "There was a splinter nearly separated, but still attached to the lower portion, of which the point had transfixed the flexor longus digitorum muscle, and this had constantly stimulated this muscle to contraction."

This shows that a voluntary muscle may be made involuntary, by the application of a sufficient stimulus. In this instance, the stimulus was mechanical, and applied to the muscle itself. In Tetanus, the same thing takes place from irritation given to the nerves, and although the will be perfect, it has not the power of controlling these actions of the muscles.

It is necessary for all the organs to have a supply of blood, not only for their support, but also for producing a proper degree of distention of the nerves, without which their

* Medical Gazette, vol. ii. p. 448. Sept. 6, 1828.

functions are not perfected. Thus, in the eye, the choroid coat stimulates the retina; for when the circulation in this is disturbed, either by too great action, or its diminution, muscæ volitantes, dimness, &c., arise. The spongy structure of the Schneiderian membrane is made for allowing a very considerable distention of the olfactory nerves. The auditory nerves are assisted by their blood-vessels; and I have known a young man in the last stage of a consumption, and reduced to the greatest weakness, deaf in the erect position, and have his hearing restored as soon as he became recumbent: his being erect did not seem to interfere with the general functions of the brain. The penis, too, requires its nerves to be distended; and these examples might be multiplied.

In the leech, the œsophagus is surrounded by the beginning of the nervous system, so that, during the act of sucking, this must be stimulated: and when the stomach is full, nearly the whole nervous system will be in that state of excitement, from distention, which is requisite for the nerves of the penis, nose, &c.

The recurrent nerve is very curious, and the circumstances connected with its distribution, are worthy of attentive observation. On the right side the subclavian artery becomes nearly encircled by the par vagum and the beginning of the recurrent; and on the left side the aorta is encompassed in the same manner, and it is very remarkable that neither of the carotids are included. I conceive this disposition was intended for producing a more extensive sympathy between the arteries of those parts of the body, which are subject to be excited by exercise, and the glottis; for when the action and distention of the arteries are increased by exercise, the recurrent nerves become stimulated, and consequently the muscles of the glottis, the opening of which thus becomes widened, so as to admit a greater and more free supply of air into the lungs. It may be supposed that any other disposition would have sufficed so long as the parts were properly supplied with nerves, and a case* is related by Dr. Stedman, where the recurrent was wanting

* Edinburgh Medical and Surgical Journal, Vol. 77, p. 564.

on the right side, and its place was supplied by numerous branches of the par vagum; but in this instance "the right subclavian artery rose from the arch of the aorta behind, and a little to the left side of the left subclavian, and forming an arch, pierced between the œsophagus and vertebral column in the region of the first vertebra of the back, and then passed over the first rib on the right side." It must be remarked that the right subclavian artery was already under the influence of the left recurrent, and therefore the usual disposition was not necessary on the right side. The same unusual distribution I have also observed in a rabbit, which was very healthy, but I never saw it in exercise, and therefore cannot determine whether its respiration was affected during that state. It is a curious circumstance, that the recurrents do not also include the carotids; but it seldom happens that the action of these arteries is much increased, except by the exertions of the voice, as in singing, &c., and therefore, if they had been included, the delicate and complicated actions of the glottis, which are produced

during these processes, might have been too much interfered with, and I believe a compensation is made for this omission by the connexion of the pharyngeal plexus with the superficial cardiac nerve.

The diseased horse termed roarer, breathes easily whilst at rest, and when moderately exercised, but when its paces are quickened very much, it appears to breathe with difficulty, and then makes a peculiar noise, which gives a name to the disease. The principal cause is a diminished size and action of one of the crico-arytenoidei postici muscles. Whilst the horse is at rest, or not hurried, the ordinary state of the glottis suffices for the admission of air, but when the circulation is quickened, and the blood has to pass through the lungs in increased quantities, it becomes necessary to have a proportionately increased freedom of respiration, and then it is that the glottis cannot be properly or equally opened by the deficient muscle, and the noise is produced.

It would be naturally expected that the inferior portion of the œsophagus should be

supplied by branches of the par vagum as well as the superior portion and the stomach; but the manner in which it is encircled by the communications of the nerves of the two sides, must be looked upon as a curious circumstance, and lead the physiologist to inquire whether it be for the convenience of directing the nerves towards the stomach, or whether some more important purpose is not at the same time effected by it. That the nerves are thus more conveniently placed than they would have been in any other situation, is what I believe no one can doubt; but the extensive communications with each other about the œsophagus must assist in promoting the functions of the nerves themselves. The nerves are not passive chords which exist for the sole purpose of conveying something from the brain, but are influenced in their functions by the actions of the parts with which they are connected; for when they have ceased to be used, they diminish and lose much of their power. As the functions of the nerves in general are assisted by their position, and their continual movement with the

parts they supply thus excites a requisite degree of action in them, I believe the act of swallowing, or the passing of the food along the œsophagus produces that state of activity in the nerves encircling it, which is necessary for the duties about to be performed by them in the stomach. It must be remarked, that the same disposition does not exist in the superior portion of the œsophagus, and that it commences after the lungs have been supplied, and when the digestive organs are to receive the remaining part of their ramifications, as the functions of the heart and lungs might otherwise be too much interfered with.

The preceding observations apply principally to the terminations of nerves, the functions of which are excited by the connexion they have with the terminations of the arteries, and to those that can be put in action through the agency of the will.

Another connexion of the nerves is with the heart and the arterial trunks, as when, by winding round them, or from some other dispositions, they become distended or excited. Thus, a mechanical stimulus produces an

action of the parts the nerves supply; and thus, also, involuntary motions are effected, as in respiration.

The other disposition of the nerves, viz. their proximity to the arteries, may, in many instances, take place for the sake of the convenience of their final distributions; but whether the motion thus imparted to them be conducive to the perfection of their functions, admits of considerable doubt. Some of them are too loosely connected to be affected very much; but others are so closely placed to them, that some excitement must be thus communicated. Dr. Parry* says, "I have seen a total loss of pulse in one arm, with coldness, but complete power of motion in that part; while the other arm was warm, and possessed a perfectly good pulse, but had lost all power of voluntary motion." It appears to me, that the loss of sensation was connected with the want of pulsation in the arteries, a circumstance which accords with the loss of sensation when the brain ceases to

* On the Arterial Pulse, p. 139.

pulsate. A somewhat similar case is also published by Dr. Storer.*

I cannot determine whether any further action is given to the nerves by the arteries which penetrate them, more than to any other parts, or which corresponds with the motion communicated to the brain.

I have made the preceding observations with the view of showing that motion is one of the powers made use of by nature for perfecting the functions of the nervous system. I say perfecting, because I think the same exquisite sensibility is possessed by the higher orders of animals, and only those which have warm blood, and a considerable arterial action.

There are other modes of connexion of the nerves, destined for exciting them to action; I shall not, however, enter into an inquiry respecting every disposition of them, but confine myself to that part which has a particular relation to my present subject.

Although there appears so much confusion

* Transactions of a Society for the Improvement of Medical and Chirurgical Knowledge, vol. iii. p. 448.

in the fibrils which compose a plexus, as in the axillary, sciatic, &c., and we are therefore unable to trace with accuracy all the fibrils from one nerve to each muscle, so as to make it appear that all the muscles for a particular action are supplied by the same nerves; we must, nevertheless, be led to conclude that these communications of the nerves are for associating those muscles in action to which all the nerves of the plexus are distributed. But how the alternate actions are so regularly maintained, cannot be easily accounted for. The muscles for effecting the different motions of the lower extremity have more distinct nerves than those of the arm; but in the leg itself, the flexors and extensors of the toes are both supplied from the sciatic. In examining the axillary plexus, we cannot tell, from the disposition of the nerves, how the different motions, as in flexion, extension, supination, and pronation, are produced. The same may be said of the muscles of the lower extremity. If one leg be moved as far as possible from the other, the adductor muscles and their nerves are put on the stretch, and

are brought into action almost without the command of the will; and I conceive, that the actions of the muscles generally depend more on the situation of the nerves, than on any peculiar connexion they have either with the brain or spinal marrow. If it were necessary that the will should be constantly directing the muscles, it could not be free to do any other service during their action. I speak more particularly of walking, and other great muscular exertions; but when very nice movements are to be effected, the will must be continually directing them, and especially if objects are to be accomplished which have not been before attempted. In the nice movements, the muscles are not so exerted as to irritate mechanically their nerves, and therefore the will must be perpetually influencing them.

A gentleman, about forty years old, had paraplegia for some years, from which he had recovered so much as to be able to walk. He says, latterly the sensation in the whole trunk, or at least all the parts supplied by the spinal nerves, have been very much impaired, but

that every part about the head and face and the sight, taste and hearing, are as perfect as ever. He says, also, when walking, he is obliged to keep the will constantly in action, and directed to his limbs, otherwise he should fall down; and this I conceive arises from the impaired functions of the nerves, which cannot be excited sufficiently by the action of the muscles of the limbs, and therefore require an additional stimulus from the will.

It is necessary, for the performance of their functions, to have the nerves supplied with blood, not only in a sufficient quantity, but also in its oxygenised state, that there may be a due correspondence between them and the brain and spinal marrow; but it is difficult to determine either the quantity or quality which is required. The nerves have many blood-vessels; but they do not admit into their intimate structure much more red blood than the medullary part of the brain. Common injections cause them to appear very vascular; but viewed in a living animal, or after death, when no particular irritation has determined an unusual quantity of blood to them, and

caused the red particles to enter vessels to which they were unaccustomed, they are white, and indeed very much like the medullary part of the brain.

That the nerves require a proper supply of blood is proved by the pain, and imperfection of the functions of the parts in which they terminate, if too great heat, or too intense cold influence them; also, if the blood be intercepted by a ligature, which may act both as preventing the accession of the arterial and return of the venous. If a large artery be tied, the functions of the limb are some time before they perfectly recover. A gentleman, advanced in life, had a severe cold, for which a spare diet was recommended. Whenever he sat up, he had great pain in the extremities, and particularly the fingers, resembling that produced by intense cold; so that he was obliged to keep principally in the recumbent position, until his usual vigour was restored by stimulating medicines and a generous diet. If he were perfectly easy and got up, the pain very soon became so severe as to oblige him to lie down again; and these symptoms were,

I believe, entirely produced by the deficient circulation.

It is also required that the blood should be properly oxygenised. In animals with cold blood this is done very imperfectly, when compared with the change in those which have warm blood; but then it corresponds with what is necessary for the functions of the brain. In animals with warm blood a degree of change is requisite for the preservation of the life of a part; but to what extent, or how long any great deterioration can be borne, is uncertain, even for the maintenance of sensation.

A man, in a bad state of health, cut his throat, and divided the trachea. He was found in a very weak state, but lived several days afterwards. He was cold, and in the most extreme state of debility. Mortification took place in many parts of the body, and the nose did not escape. The lungs were found diseased; and this circumstance, I conceive, with the debility and the further impediment to the due oxygenisation of the blood produced by the thickening about the wound in the throat, diminished the powers of the parts

so much that their vitality could not be supported.

A man, twenty-six years of age, wounded the femoral artery in the middle of the thigh. Blood flowed very freely from the inferior divided end, so as to lead to a probability that the circulation would be carried on well by the anastomosing branches. Both extremities of the artery were tied.

Four hours after the operation the foot was not so cold as it was before ; and on pressing forward the blood in the veins, they were observed to fill again. He had no sensation in the foot except about the heel. The foot and part of the leg mortified, and on the sixth day after the tying of the artery, the limb was amputated above the knee.

After the limb was amputated it was injected, and from the weakness of the coats of the arteries, the injection was extravasated in almost every part of it. There was an effusion of serum into the whole cellular membrane, and between the fasciculi of the muscular fibres. The popliteal vein had burst just at the termination of the tibial veins. The

nerves were uninjured. The injection passed well through all the arteries, even in the foot, and could be traced in those of the smallest nerves. It appeared from this dissection that the collateral arterial branches were capable of carrying on the circulation sufficiently for the maintenance of the vitality of the limb, and that the mortification was entirely owing to the impossibility of the return of blood by the veins. On the third day after the amputation he felt his toes for the first time; and his not having done so before, proves that the want of the proper change in the blood impeded the functions of the nerves before the amputation, and that the sciatic nerve itself had suffered from an extension of the same cause.

It is also required that the integrity of the nerves be, to a certain extent, perfect. Tumours, contusions, pressure on them, and the contact of poisonous substances, destroy their power of acting in concert with the brain. The application of opium, tobacco, &c., to the skin, affects the nerves.

It seems difficult to decide whether the

nerves perform functions independently of the brain and spinal marrow, and similar either in general effect or importance; yet, as we observe them larger when higher purposes are to be accomplished, and less when a more moderate action is required, and that they are larger in proportion to the size of the animal, and not to that of the brain, we can hardly help concluding that they have actions of their own, but bearing a considerable resemblance to those of the brain.

When we observe the extensive distribution of nerves in the face, and see them attached to a trunk very small in proportion to their size and number, we must conclude that important purposes are performed by the nerves themselves. In fishes, and all animals with cold blood, the brain bears no proportion to the nerves; and, in the lowest animals, is either entirely wanting, or of such a nature as not to be compared with the brain.

Dr. Monro* says, "I have long thought, and endeavoured to prove, that our nerves, inde-

* On the Nervous System, p. 35.

pendent of the encephalon, possess an energy, or principle of life, which they derive from their proper pia mater and its vessels; or that the limb of a frog, in which the circulation continues after the sciatic nerve has been cut out, has its minute vessels actuated by an energy which may, strictly speaking, be called nervous, and which seems to be analogous to the energy which operates on the parts of these animals; for instance, the echinus marinus, in which I have not found any organ resembling our brain, or is perhaps like to the energy by which the parts of the vegetable kingdom are actuated."

Sir Astley Cooper* says, "I have always thought, that although sensation and volition depend upon the brain, spinal marrow, and nerves, that the involuntary functions depend principally upon the nerves."

I have briefly stated what appeared necessary respecting the structure and functions of the brain and spinal marrow, and their nerves; and I shall now make some observations on

* Treatise on Dislocations and Fractures of the Joints, p. 552.

the other great part of the nervous system, viz. the grand sympathetic nerve.

This extends from the crossing of the sixth nerve in the cavernous sinus, to the extremity of the sacrum. Its general form is nearly the same on each side of the body, inasmuch as there is a chord which is evidently its prolongation or continuation, although in many subjects it neither corresponds in thickness, nor the number nor size of its ganglia in the two sides.

The prolongation, and all the nerves attached to the ganglia, are like those proceeding from the spinal marrow, before they have escaped from the sheath formed by the dura mater; and the resemblance consists in their not having the same appearance of the neurilema the spinal nerves have, after they have left the ganglion to which they are attached; and they are of a pearly, or white appearance, except when inflamed or coloured by an exudation of blood or bile, &c.

The ganglia of a healthy subject are firm, nearly white, or pearly, and have not any appearance of blood-vessels. When cut into

they have a somewhat pulpy appearance, nevertheless every part is firm; but when pressed, a very small quantity of blood oozes out. They appear to be supplied with blood pretty much in the same manner as the conjunctiva and sclerotica of the eye, and exhibit after a minute injection, or inflammation, a great number of vessels.

A ganglion appears in the following manner. For instance. The termination of the splanchnic nerve divides into an infinity of ramifications, which become entirely blended in the substance of the semilunar ganglion; the nerves afterwards arising from the ganglion are seen first in its substance as very minute white streaks, and these collect into threads, which join together to form branches to be distributed to the viscera. The structure of the other ganglia of the grand sympathetic, appears nearly the same as that of the semilunar; the nerves proceeding from them to the spinal nerves, begin in a similar manner, and when they approach the spinal nerves, the minute threads of which they are composed separate, and become incorporated with their fibrils.

The grand sympathetic is of great extent, and goes to parts performing different and peculiar functions.

The superior cervical ganglion in man, is always oblong, and its length varies very much in different subjects. The inferior cervical ganglion is flat, but thickened and nearly square. The first thoracic is oblong, broad above, and narrower at its inferior part; the rest of those placed in the thorax are very much extended, flat, and generally like membrane. In the abdomen, the semilunar is flat, but thick, and of no determinate shape. The lumbar and sacral are a little thicker than the thoracic, but not quite so much extended. In some of the mammalia, as the dog, calf, and horse, the superior cervical ganglion is more rounded, and does not vary so much in extent as in man; the inferior cervical is different from the same in man, being frequently united with the par vagum, which has an enlarged and peculiar appearance at this part: the first thoracic is the same as in man: the other thoracic are much smaller, not so extended, and have not so much a membranous appearance.

The semilunar is thinner in the dog in proportion to the size of the body, than in man. Although the variety of shapes may give some peculiar properties, I nevertheless think that they differ from each other in man, for the more convenient attachment of the branches entering and receding from them; and in some instances, as in the thorax, for affording a more extended and convenient surface for being acted upon by the blood-vessels. The ganglia and their branches vary according to the general conformation of the body in health, and very considerably too, according to the state it is reduced to by disease; for in very delicate persons they will be found smaller and thinner, and their nerves more slender than in health, and this state will also bear a proportion to the length of time the disease has taken to produce death.

As the superior cervical ganglia in man vary so much in size, it may be reasonably presumed, that these have acquired such increased dimensions, from a greater extent of connexion with parts more freely exercised in one man than another, as in several animals

these seldom vary either in size or shape; nor is there such a difference in the functions of the organs connected with them as in man, for the hearing, voice, &c., are not much more powerfully or frequently exercised in them; there is indeed so much similarity in their habits and occupations, that very little more exertion becomes necessary in one than another.

For the sake of convenience, we say a nerve has its origin in one part, and termination in another, and thus it becomes more easy to understand the course of a nerve. The grand sympathetic is said to arise from the sixth and a branch of the Vidian, but it is difficult to reconcile this altogether with what is usually described as the origin of a nerve. If the sixth only be examined, we may suppose that the filaments proceeding from it, form the origin of the grand sympathetic; but if the carotic canal be laid open, and the grand sympathetic carefully traced from the superior cervical ganglion; if the second trunk of the fifth, and also the third trunk, be cut off just after they have left the Gasserian ganglion, so that the exterior edge of this ganglion may

be sufficiently raised, it may be observed that the branches on the carotid artery not only ascend to join the Vidian and the sixth, but some filaments are also communicating in a similar manner with the Gasserian ganglion. In the ox, dog, sheep, &c., it is evident that the branches ascending from the superior cervical ganglion, are principally for connecting it with the Gasserian ganglion; and although a communication with the sixth takes place in some animals, yet it does not in others, and this is generally so insignificant in comparison with the branches given to the Gasserian from the superior cervical ganglion, that no doubt can be maintained, that the branches proceed from the grand sympathetic to the sixth; and although in man it may appear more as if the branches were passing from the sixth to the grand sympathetic, yet when all these circumstances are taken into consideration, we must be led to conclude that in man the branches ascend from the superior cervical ganglion to communicate with the sixth, the spheno-palatine and the different parts of the Gasserian ganglion.

When we observe that branches are sent from the first cervical ganglion of the grand sympathetic, along the branches of the internal carotid artery, and that these communicate with other nerves, in nearly the same manner as those which pass on the internal carotid; when we observe, too, that branches are sent from one or more of the cervical ganglia, and the first dorsal on the vertebral artery, we must presume that those on the internal carotid artery, usually termed the origin of the grand sympathetic, are for somewhat similar purposes as those distributed on the external carotid; for had one branch only been sent to the superior cervical ganglion from the sixth, and the inferior branch of the Vidian, then we might have supposed that these were for the purpose of forming a sympathetic communication only; but as filaments are plainly given to the internal carotid, and the sheath which lines its canal, and as branches are sent upwards from the sixth on the internal carotid, and as there is a communication between the sixth and filaments from other parts of the fifth, which have their peculiar terminations, we may pre-

sume, so as to justify our former assertion, that the branches do not pass on the internal carotid and other arteries for a mere convenience, but for the purpose of supplying them, and the parts about them, with a peculiar nervous excitement.

The ganglia of the grand sympathetic nerve appear to consist of a substance sui generis, in which the nerves entirely terminate, and which is quite different from the nerves going to them; but this structure is not absolutely required, as it is the same in some animals, as the dog, cat, &c., and different in the calf, and ass, inasmuch as it has the appearance of a plexus.

When new properties are required in nerves, or when their actions are to be modified, ganglia are attached to them, and these vary in their structure according to their uses in different parts of the body, and the corresponding ganglia also vary in different animals. When food is to be procured, or eaten, or rejected by the smell, it becomes necessary to accommodate the nerves of the nose to the requisite properties; and thus it is that the olfactory

nerves vary so much, either in the portion of brain to which they are attached, or by the form or structure of the ganglia appended to them.

As the iris has the same properties as other muscular contrivances, and as its action is necessary for the perfect functions of the eye, but as it was required that it should have peculiar qualities, and not much dissimilar from those of the involuntary muscles in general, the lenticular ganglion was formed to be capable of imparting that mixed nervous excitement, which makes the actions of the iris independent of the ordinary functions of the third nerve, at the same time that it is assimilated with them in a sufficient degree to produce a harmonious co-operation. As the fifth supplies the exterior apparatus of the eye in a considerable degree, so it would reasonably be expected that its interior should be associated with it by contributions from the same nerves, and as these are principally for sensation, and as the muscles of the eye receive nerves, which are entirely for exciting muscular action, it becomes necessary to associate

nerves from both sources by means of this ganglion; and as the actions of the iris are principally controlled by light, so it is requisite it should be composed of nerves both of sensation and motion. This is the only example of an external agent immediately exciting muscular contraction without the interposition of another part. Cold, indeed, affects the skin, and then by connected agency, muscular parts, as the bladder, &c. I conceive the lenticular ganglion exists for exciting the peculiar actions of the iris, and that it should not be considered as part of the grand sympathetic, as the communication with this nerve is very indirect, and does not correspond with the general order of its ganglia.

I have stated that the lenticular ganglion may exist for uniting together nerves of sensation and motion; but when the lenticular ganglion is entirely formed by a branch of the third, it may only be for making the motions of the iris sufficiently independent of the actions of the third in general. When it is formed of the third alone, the sensibility of the iris must either be produced by it, or through some

sympathy between it and the retina; but as no communication is particularly formed between these nerves, it may be presumed that the third can produce sensation as well as motion.

The third is sometimes affected so that it cannot perform its functions; and there is a paralytic state of its muscles, as may be known, not only by the inability to direct the usual motions of the eye, but also by the falling of the upper lid; the motions of the iris are at the same time so affected, that the pupil becomes dilated, and cannot contract. These circumstances show that the ciliary ganglion is not an independent part, but that it receives its power of causing contraction, from the third. In this case, the sight need not be destroyed, but the functions of the optic nerve may continue perfect; so that I conceive the powers of the fifth may remain also in the ganglion, notwithstanding the functions of the third are impaired. *Travers relates cases of complete blindness, in which the eyes were perfect in appearance, and the iris was vivacious; and

* Synopsis, &c. p. 189.

these prove that the iris is not moved through the retina, but that the ciliary ganglion gives the power of feeling light to the iris.

It must appear from the observations I have made on the ciliary ganglion, that the general properties of a nerve are conveyed through a ganglion to the parts on which the nerves proceeding from the ganglion are distributed. And I believe that a stimulus, or any irritation directly made in the ganglion itself or its branches, can call into action those nerves, the branches of the ganglion communicate with. The following observations are intended for proving that the nerves of the brain and spinal marrow may be excited through the communicating branches of the grand sympathetic.

Diseases of the alimentary canal frequently produce partial affections of the limbs, and sometimes of a single finger. One gentleman had generally a pain in the fingers whenever he had a motion, another when the bladder had been allowed to become too much distended. A gentleman about forty years old, has pain in various parts of his body, but most

frequently in his limbs. It resembles the tic douloureux in violence: it is sometimes in a small spot in one leg, sometimes in the other, in one arm or the shoulder; and when in the latter part, he is usually very sallow. His complaints arise from a disordered state of the digestive organs, and when the pain is in the lower extremities, the cause is generally in the bowels, and consists in a lodgment of fœces in them, and is relieved by purging medicines. In cholera morbus, cramps in the lower extremities are very frequent. Spasms of the muscles in tetanus arise from connexions between the spinal and cerebral nerves, and the grand sympathetic. Does not irritation in the nose and larynx excite the muscles of respiration through the communications between the nerves of these parts and those of the respiratory muscles? Is not the abductor muscle of the eye affected by disorders of the digestive organs, through its connexion with the visceral nerves? In angina pectoris the pain in the arms no doubt arises from the connexions of the cardiac nerves with those of the arms, and as the branches

of nerves accompany principally the ramifications of the coronary arteries, these may become affected by the same action which produced the ossification, or the thickening of the coats of the arteries, and thus excite the peculiar symptoms.

Examinations of the nerves by dissection, prove that irritation can begin in any part, and be conveyed by the nerves of an injured part to those of the ganglia of the grand sympathetic, as I have already stated in my Essay on Tetanus. It can also be conveyed to the ganglia from any other parts, as the viscera, &c. A boy, who died with a calculus in the bladder, and disease of the kidneys, had all the ganglia in the abdomen much more vascular than those in the chest. A man, who had an inguinal hernia of the left side, and was not operated on, died at the end of five days; about three feet of the jejunum, and very highly inflamed, were contained in the sack, and the intestine above the protruded portion was also inflamed, but not in so great a degree. There was the least possible vascularity in the right semilunar ganglion, but there

was a much greater degree of it in the left. A gentleman died with inflammation of the liver, and pleura of the right side, and the right lung was very dark and congested. The pleura of the left side, and the left lung, were almost natural. The semilunar ganglion of the right side was very vascular, and that of the left was vascular, but not near so much so as the right. A child died of hydrocephalus internus. The semilunar ganglia and the right superior thoracic were very vascular, but the left superior thoracic was not near so much so. The right par vagum was stretched by very large absorbed glands at the root of the lung, and was very vascular at this part; on the left side, the glands, and also the par vagum, were natural. The mother of this child died with an enlarged liver, and ulcerations of the intestines, without any marked symptom of disease of the chest: for the last ten days of her life, she had fever, with a furred and brown tongue; and in the last few days, her cheeks became flushed, which had always before been pale. The right semilunar ganglion was quite pale, and free from vessels, and also the left, except

about one third of it at the termination of the splanchnic nerve. The superior thoracic ganglia of each side were very vascular, or inflamed. The lungs were tuberculated; and there was active inflammation, and an effusion of coagulable lymph on the pleura, but most particularly on the right side; and these appearances of the ganglia were, no doubt, produced by the inflammation of the pleura, which had come on in the last ten days.

In the preceding cases, the irritation spread from the affected organ to the ganglia of the grand sympathetic, and produced fever.* A case of idiopathic tetanus, is related in my Essay on that complaint, in which the prxoimate cause was irritation, produced by worms and unhealthy fœces, on the coats of the intestines, and which was conveyed from thence to the ganglia of the grand sympathetic, and then to the spinal and cerebral nerves. This proves that such an excitement may be given to the ganglia of the grand sympathetic, as to bring into action the nerves with which these

* Essay on Tetanus, p. 51.

communicate. One side of the body in this case was affected in a much greater degree than the other; "he can move the left leg, and draw it up a little with great exertion, and very considerable pain, but has not the same power over the right. The arms are also affected in the same disproportion." "After death the limbs of the right side remained quite stiff, but those of the left were in a considerable degree relaxed."

"The ganglia of the grand sympathetic nerves were examined with very minute attention. In all of them there existed decided marks of irritation. The vessels usually pale and colourless were injected with red blood, and the same was observed in some of the intermediate portions of nerve. The vascularity could be distinctly traced before their removal from the body, and immersion in cold water for some time, did not diminish it. The left semilunar ganglion exhibited a few vessels, but the right was injected in a beautifully minute manner, quite as much so, when seen through a magnifying glass, as the conjunctiva in a state of high inflammation. The

same distinction, though not in the same degree, was observed between the two sides in all the portions of the grand sympathetic nerves which were examined." In the same way, irritation is conveyed from the intestines to the nerves of the limbs, in severe cases of cholera morbus.

All these circumstances, as well as others, show that each branch of the grand sympathetic nerve has its peculiar and specific uses, and influences, and is influenced by the precise part with which it is connected, and that the grand sympathetic cannot be considered as a whole, so as to be separated from the other parts of the nervous system. Although we cannot demonstrate the precise point at which each fibril of a nerve communicates with the filament of the grand sympathetic, we may nevertheless, from pathological observations in particular, rest assured, that this takes place.

At the same time, that I am fully persuaded the grand sympathetic nerve exists principally for the purpose of supplying parts with a peculiar excitement; it also exists for con-

necting one part of the nervous system with another; that whilst it makes the organs supplied by it sufficiently independent, it also produces that concert which is necessary for the maintenance of the general accommodation of the whole. It can also, through its union with the other nerves, call into action the parts these are given to, either through the stimulus imparted to it by the motion of the heart and arteries, or by morbid changes, such as inflammation or irritation from various causes. I also believe it is intended for maintaining such a sympathetic communication as appears necessary for producing those simultaneous actions, and their consequent harmonious sensations throughout the system, which constitute a state of health; and on the contrary, that it performs not less important services, by guarding against diseases, for when any part of much importance becomes seriously affected, its extensive agency excites uncomfortable sensations throughout the system; and thus the patient is under the necessity of resorting to remedies, whose timely use arrests the disease; whereas did not the

system so readily sympathize, the disease might go on to such an extent, as would either prevent the restoration of the part it had attacked, or even prove destructive of life. Another important office produced by it is after severe injuries. If the restoration were to be effected by the part itself, it would often fail in accomplishing it, as we have the opportunity of witnessing in bad constitutions, when very extensive mischief has been committed. No re-action then takes place, and death is the immediate consequence of the injury; but in a good constitution, this system soon receives a sympathetic feeling from the injured part, and from its peculiar connection with the vascular system, excites that degree of action in it, which is suitable for the restoration of the injured part, and by which alone its recovery can be effected. Should it be said that there is no need of such a monitor as the grand sympathetic, when the brain so readily receives impressions from every part of the body, and over which it has so much control; I should urge in reply, that the brain has other functions of so much importance to

perform, that its being thus impressed would too much interfere with the parts necessary for the maintenance of life, or we should have such a frequent disturbance of the intellectual faculties, as must embarrass very much the operations of the system, and tend to very frequent derangement of the mind, and also to a much more speedy termination of life. It were wise, therefore, that an intermediate system was made, one that should be connected with all the parts of the nervous system, but still be so independent of them, as not very materially to interfere with their functions on every slight occasion.

As it is impossible for the anatomist to trace many of the nerves to their extreme terminations by means of instruments, he must either be satisfied with conjecturing that such and such nerves are distributed on particular parts, or he must have recourse to reasoning, founded on the facts he can collect from morbid anatomy and experiments. It is for these reasons I introduce the following remarks.

CASE.

William Sharpe, eleven years of age, had a purulent discharge from the left ear, which began in the spring of 1824, kept gradually increasing, and became very offensive. Blisters were applied many times behind the ears, and tonic medicines administered without producing any good effect on the local disease, although his general health was improved by them. About the end of March, 1825, the integuments around the ear became swoln and painful, and the whole side of the face was enlarged. At this time the discharge was very copious and offensive; he had frequent pains in the head, and over the left eye. On passing a probe into the meatus, the bone was found to be denuded; his health had declined, and tonic medicines were of no use. In December, it was observed that the left side of his face was nearly paralytic; he had violent pains in the head and face, which were much aggravated at night,

and for which he took an opiate with some relief. He was frequently drowsy, and sometimes nearly comatose. In February, 1826, there was some inflammation of the conjunctiva of the left eye, which went off in a few days. On the 12th of October, the left temporal bone appeared to be quite loose in the wound, and was easily extracted. About a week before this time, his right eye became amaurotic, the pupil was dilated and the lids closed. On the 14th he became insensible, but cried out when touched. On the 16th a large vesicle formed at the inferior part of the left cornea, and the greatest part of the cornea had become opaque. The right cornea was not altered. He had slight convulsions, and when the left side of his face was touched, he flinched. He died in the night.

He walked about until the last few days. He had generally a good appetite. His food appeared to digest properly, and indeed all the functions of the viscera of the chest and abdomen were perfectly performed. He could talk distinctly. The left side of his face was nearly paralytic, and the left side of the

nose was completely drawn to the right side. When he cried out, so as to exert the muscles of the face much, it was observed that those of the right side had very great power over those of the left; but the mouth, when shut, appeared even, and would not then have been supposed to be paralytic. From the end of last March, the pain in the right side was very severe, he shrieked very much, and the opiate did not relieve him. His manner became altered, and he was unwilling to answer questions. He was generally easier in the day, and spent much of it in sleeping in the sun.

EXAMINATION.

This took place on the 17th of October, at 11 A. M.

The dura mater was rather more vascular than is usual. The tunica arachnoidea was much thickened, and especially on the right side, and there was much fluid between it and the pia mater. The pia mater was very vascular. There was much fluid in the lateral

ventricles. The portion of brain which lay over the part from which the temporal bone was separated, was protruded into a hernia, and the inferior cornu of the lateral ventricle was thereby drawn out of its course; the brain at this part was softer than natural, but the rest of it was sound. The origins of the nerves were distinct.

The third branch of the fifth pair was in a state of ulceration, near its beginning from the Gasserian ganglion; the gustatory, dental, and buccal nerves were however quite attached to it, and indeed did not appear to have suffered.

The portio mollis and dura terminated in a bulbous mass on the dura mater. The portio dura could with difficulty be traced in the face near the edge of the jaw, on account of the inflammatory process which had been going on there. It could, however, be distinctly seen to communicate with the dental nerve, and then terminate in a confused mass, which formed the walls of the cavity containing the exfoliating bone.

The par vagum, the glosso-pharyngeus, and

the accessory nerve were sound, and passed just behind the walls of the same cavity.

The internal carotid artery, from above and below, could be traced as far as the walls of the cavity, and was then lost. It was reduced to a small size however, before it reached the walls of the cavity, and was impervious.

The superior cervical ganglion of the grand sympathetic nerve, terminated in the walls of the cavity. The branches given off from the sixth, which usually go to the superior cervical ganglion, were very small, and terminated with the internal carotid; the superior cervical ganglion itself appeared natural.

The vidian nerve was perfect from its connexion with the spheno-palatine ganglion. The superior branch could be traced a short distance, but soon became much smaller than usual; the inferior branch could be traced a little way, it then became very small, and the branches from the sixth could be traced the same distance, and both of these terminated with the internal carotid artery, in the walls of the cavity.

The condyloid process of the lower jaw was exfoliating. The whole of the temporal

bone had exfoliated, and to compensate for it, the orbital plate of the frontal bone had become unusually thick, and all the bone in the neighbourhood of the disease had a firmer texture than is observed at his age. The pericranium round the opening at which the hernia protruded, was much more vascular than in the other parts.

A considerable portion of the brain had protruded like a fungus, into the cavity left by the exfoliated bone; it had been forming gradually, and was, no doubt, the cause of his death.

The quantity of fluid contained in each ventricle was the same, and therefore, the blindness of the right eye did not depend on this as its cause, for vision remained in the left after the right one was blind.

In the examination, a black pin was found in the cavity, which had contained the exfoliated bone. Pins had not been used to confine the dressings, the question therefore is, whether it had been forcibly introduced into the ear, and occasioned the disease, but this could not be ascertained.

It will be seen from this very curious case,

that the grand sympathetic may be partly destroyed, and the general health remain unimpaired, as we have a right to presume after a due consideration of all the circumstances which have been related. We may conclude, therefore, that although the grand sympathetic produces a general sympathy in the body, yet that each ganglion has a somewhat local influence, inasmuch as it more particularly connects the parts giving and receiving branches from it, so as to associate them in complicated operations. Both the spheno palatine ganglion, and the vidian nerve were first of their usual size, then each branch of the vidian was diminished. Can it be presumed from this, that the branches of the vidian are going to, and not coming from the grand sympathetic?

The functions of the portio dura must have been entirely suspended, and, from the evenness of the mouth when at rest, and from his ability to speak so well, I cannot help concluding that the branches of the fifth had very considerable power in exciting the action of the muscular structure of the lips.

EXPERIMENT.

July 3, 1827. I cut out a portion of the sympathetic nerve of each side in the neck of a rabbit, which was nearly full grown. I also removed a portion of the left par vagum. It ailed very little after the operation, and in a few days appeared quite well, and has remained so ever since. It ate with a good appetite, and was always lively and playful. It was killed October 1st.

The right sympathetic had united by very minute filaments.

The upper extremity of the divided par vagum had a bulbous enlargement, and this and its lower extremity, and the extremities of the left sympathetic, were united together by a considerable plexus of small branches.

All the parts of the body were well grown, and in every respect perfectly healthy in appearance.

EXPERIMENT.

July 3, 1827. I cut out a portion of the sympathetic nerve in the neck of a rabbit, exactly like the one which was the subject of the preceding experiment. In the evening he appeared well, and ate with a good appetite. He never ailed any thing after the operation, and did not appear to suffer the slightest inconvenience. He was killed September 17th, and was well fed and perfectly healthy.

The right sympathetic was united by some small filaments, and the superior portion was also united to the par vagum; the left was also united by several filaments, which formed a plexus. Every part of the body appeared quite sound.

Dr. Monro* had made similar experiments, the results of which correspond with mine,

* Elements of Anatomy, vol. ii. p. 498.

but as he had not given the appearances after death, I repeated them.

These experiments confirm the opinions that the different parts of the sympathetic nerves, have in a very considerable degree a local influence, for the animals, which were the subjects of them, continued to thrive, to eat well, and be playful; and as far as could be decided by observation, none of the general functions of the system were in the least influenced by the injury to the nerves. No doubt, some particular functions were disturbed, but in what degree is very difficult to determine; but I think it not improbable that if we could be sufficiently acquainted with the habits of the animal, to be enabled to watch the effects of stimuli applied to the nose, or other parts above the division, and which were connected by it with different organs below the division, we might learn, that at the same time the ganglia are exerting a local influence, and are convenient for uniting several parts together, we should also discover that they can transmit particular impressions to a distance.

Having premised these observations respecting the nervous system generally, I shall endeavour to show that some of the nerves are peculiarly placed for the production of specific effects, and that these could not be attained so well by any other contrivances. But the particular object of my present consideration, is the connexion of several nerves with the heart and arteries, for the purpose of effecting the involuntary act of respiration.

Some may believe that respiration is a peculiar power implanted in the body, and therefore not to be accounted for. It is a combination of mechanical and chemical operations, performed by a complexity of organs for effecting such changes in the blood as are necessary for the preservation of life, and producing other actions, which are peculiarly conducive to the comfort and convenience of man; and it is therefore reasonable to inquire, not only how these individually act, but how they afford that reciprocal assistance which is determined to such important ends.

The ordinary act of respiration is involun-

tary; but there is a power superadded which is voluntary, and this I shall first briefly notice.

If we examine the cervical nerves, we shall find there is an extensive connexion between them, and not only through their own branches, but those also of the grand sympathetic. The cervical nerves are distributed to muscles which may act singly, but cannot thus produce any continued exertion, because other muscles must be generally acting simultaneously with them, as in the motions of the head and neck. If these connexions between the nerves therefore did not exist, it would be difficult to conceive how any regular and synchronous motions could be carried on. Many of these muscles move parts in concert with others performing different offices, viz. in those respiratory acts eliciting the voice, as in speaking, singing, &c.; but these are moved in unison likewise by their connexions with other nerves. Many of them when not performing the usual motions of the head and other parts, assist the common respiratory actions, when the body is violently agitated or exercised, or

when there exists any disordered state of the organs of respiration, which prevents their easy functions. I believe one principal intention in connecting the nerves, which pass to the muscles of the shoulder and sternum, is for commanding a sufficient and simultaneous steadiness or fixedness, for promoting the action of the muscles which pass from them to the os hyoides and larynx, and which would not admit of such nice motions, unless the scapula and other parts could be brought to a requisite degree of constraint. The assistance of many of the muscles is only wanted for some extraordinary exertion, or when there exists an obstruction to the usual mode of respiration.

The muscles concerned in ordinary respiration are supplied almost entirely by the phrenic and intercostal nerves, which are in every way similar to the cervical.

The phrenic nerves supply muscles which are acting continually; they arise from nerves which are not different from those supplying muscles for voluntary motion; they are indeed connected with branches of the grand sym-

pathetic; but it is difficult to conceive that they should, on this account alone, have the power of producing the perpetual action of the diaphragm. As the will has very little control over this part, are we to suppose that it has the power of contraction independently of the nerves? Experiments prove the contrary. And therefore, as there is nothing peculiar in the phrenic nerves, I conceive the motion of the heart stimulates them to produce contraction of the diaphragm, and I think this very probable, because the heart decidedly acts first, although the action of the heart is afterwards dependent in a great measure on the continued action of the respiratory organs.

The phrenic nerves have extensive communications with several of the cervical nerves, and also through them with the descending branch of the ninth; and there is also another junction frequently found between the phrenic and the descending branch of the ninth, on the pericardium. These communications no doubt associate the muscles supplied by these nerves with the diaphragm, and thus produce

their voluntary action and assistance whenever the exercise of the voice, or any difficulty of breathing, requires it. But there are other actions of these muscles associated with the respiratory organs, and which are almost involuntarily excited when the breathing is not easily performed, and these, I conceive, are through the branches of the grand sympathetic, which communicate with the cervical nerves, and particularly those which pass up with the vertebral arteries.

I have stated that the phrenic nerves are stimulated by the motion of the heart, and that the action of the diaphragm is excited in consequence. The intercostal nerves are also stimulated through the grand sympathetic in a very similar manner, and the muscles they supply are thus also excited to action. The phrenic nerves communicate most commonly with the last cervical ganglion of the grand sympathetic, and this union may be supposed to exist for making the action of the diaphragm involuntary; but the branches forming it are very small, as compared with those given to the intercostal nerves, and do

not afford a sufficient assistance; and I conceive, therefore, it is principally for associating the phrenic with the intercostal nerves; and it is calculated for this end because it so particularly joins the branches of the inferior cervical ganglion, which pass over and also underneath the subclavian artery so as to encircle it, and those branches of the grand sympathetic, which unite with the intercostal nerves, and are so peculiarly situated with respect to the intercostal arteries; and as these are all calculated for the same purpose, they therefore require the phrenic nerves to be connected with them. And as the heart and arteries are all in action at the same moment, so the same impulse is thus afforded to all the nerves given to the muscles of respiration.

From the never-failing connexion of the intercostal nerves with the grand sympathetic, I cannot hesitate to conclude that it associates them, and particularly for the involuntary action of respiration; for, although it be connected with all the spinal nerves, yet, after it has communicated with those which supply the abdominal muscles,

it appears to take another disposition; and we must, therefore, conclude that it is through this connexion that the actions of the chest are so well performed.

There is no particular communication between the dorsal nerves after they have left the spinal canal; and, therefore, unless they are connected together before they are extricated from the medulla, or, rather, before they have left it, to be joined into a bundle, I do not see how they are to be associated for producing the synchronous action of all the muscles they are distributed to for respiration, except by the junctions with the grand sympathetic. If they had been connected with each other by their own substance, they might indeed have been fitted for a certain motion, which would have been constrained and limited; but, by the connexions of the phrenic and the branches of the grand sympathetic, with the heart and arteries, we see them beautifully adapted for being acted upon by the same stimulus; and I do not know by what other means so many complicated and important parts could

have been brought into simultaneous and involuntary actions. To have supposed that they were produced by the brain, was at variance with the facts we possess respecting the functions of this organ; and then indeed, man would have had so much control over those vital functions, as to have been enabled to stop them, and thus to have sacrificed his life on every disappointment.

It may be difficult to understand how the stimulus of the blood-vessels, applied to the grand sympathetic, produces the respiratory actions of the chest. It is however probable that the cause of the action of the muscles of the chest, resides in the impulse given by the heart and arteries to the phrenic and the grand sympathetic nerves; and although we cannot trace the precise communications between the branches of the grand sympathetic, and the different fibrils composing each spinal nerve, so as to be enabled to state what portion of muscle is particularly connected with the grand sympathetic, we nevertheless may presume that the branches of the grand sympathetic have specific terminations in the fibrils

going to particular muscles, and can excite certain parts of them; and although these have not been demonstrated, yet, I trust, some peculiar mode of dissection will enable us to clear up this point, and particularly with the assistance of the microscope.

If the grand sympathetic did not thus communicate with each intercostal nerve, it would be difficult to conceive, how sneezing or coughing could be so momentarily produced; and all the respiratory muscles brought so regularly into action, as they are in an infant immediately after birth, and before such actions can have been, by any possibility, acquired.

In answer to this, it may be suggested that the young of some animals, as the foal, calf, lamb, &c., can direct their muscles very soon after birth, so as to be enabled to walk. The will can, indeed, in them very early exert an independent influence, and the voluntary muscles attain an apparent perfection without much previous preparation. But respiration must be performed in every variety of the mammalia, without the least delay after birth,

and when the animals are in a most helpless state, and have no voluntary power, unless the act of sucking be considered as such. If life had depended on so uncertain a cause as voluntary action for respiration, but few would survive the shortest period after birth, and therefore a different power was formed. And I think it may very properly be concluded that the action of sucking and swallowing so soon after birth, may be excited through the same cause as respiration, viz. the action of the arteries on the nerves of the alimentary canal, and the pharyngeal plexus and other branches of the grand sympathetic.

Dr. Monro* says, "after the intercostal nerves have passed between the vertebræ, they are connected with the great sympathetic nerve, and form ganglia." And in a subsequent paragraph he writes, "May not, says my grandfather, the communications of all these nerves be one reason why the parts act so uniformly and conjunctly in respiration,

* Elements of Anatomy, vol. ii. p. 526.

and conspire together in the convulsive motions of coughing and sneezing."

In man, branches of the cervical portion of the grand sympathetic, and also of the first dorsal ganglion, are sent up with the vertebral artery, to be joined with the cervical nerves. In the mammalia, the corresponding branches are given off from the first dorsal ganglion; and, in birds, a similar disposition forms the continuation of the grand sympathetic, and which is most intimately connected with each cervical nerve. In man, the inferior cervical ganglion gives off a branch, which invariably passes over the subclavian artery to the first dorsal ganglion, so that this, and the continuation of the grand sympathetic, which goes underneath, completely encircle it: it communicates also with the phrenic and cardiac nerves. Besides these, in man, the superior intercostal artery passes between the first dorsal nerve and the branches going from the first dorsal ganglion to this nerve, so that this artery becomes also encircled. The second branch of the artery is similarly

situated. All the other intercostal arteries pass behind the prolongation of the grand sympathetic, and many of them also through the loops formed by the junction of each of its branches with the intercostal nerves. Although there is a varied connexion between the intercostal arteries and the branches of the grand sympathetic, in different subjects; yet their contiguity is always so close, that after exposing them by dissection, and injecting water by the aorta, a very evident impulse is given to these nerves by the arteries. The intercostal veins also pass behind the prolongation of the grand sympathetic to the vena azygos; and I cannot determine, whether these do not keep up a considerable distension of the grand sympathetic, or whether the different states of fulness of them, during expiration, may not make some difference in the stimulus afforded to the nerves.

The subclavian artery on the right side, and the aorta on the left, are almost encircled by the par vagum and its recurrent branches. This disposition, no doubt, connects the ac-

tions of these arteries with those of the glottis. The par vagum too, may be also stimulated by passing over the subclavian artery and the aorta. When respiration is carried on in its ordinary gentle manner, the branches of the par vagum at the back of the lungs do not appear to be extended; but when the inspiration is very forcible, the great dilatation of the trachea, before it enters the lungs, extends them in some degree, and thus stimulates them.

It thus appears that the motion of the heart and blood-vessels sets in action and produces the regularity of respiration, and that it is effected not only by the association of the nerves, but principally by the mechanical excitement of the nerves which pass over those parts in motion. By the communications of the grand sympathetic with the phrenic, and also with the dorsal nerves, an association is produced between them; and the motions of the heart and the subclavian and intercostal arteries stimulate mechanically the phrenic nerves, and the branches of the grand sympathetic connected with them and the

intercostal nerves, at the same instant. The communications of the grand sympathetic with the par vagum may produce an association between these nerves and the lungs; and some degree of the same impulse may be also given to them by the lungs themselves.

It may be asked, why there exists so intricate a plexus as the pharyngeal? I believe it is in a considerable degree for the association of the parts concerned in respiration and deglutition, but particularly in the production of the voice and speech. Thus it may be necessary that there should exist a communication between the nerves given to several muscles of the neck, and those distributed to the pharynx, larynx, tongue, and face, as various parts of these different organs are at the same time in action, during the complicated operations going on in the exercise of the voice, &c.; it also furnishes the coats of the arteries with its ramifications, and it is principally for this reason that it receives so many branches from the grand sympathetic. It is undoubtedly necessary that the various organs of the body should have the supply

of blood for the completion of their operations regulated during the time they are in action, that all the parts ministering to the perfect functions of each organ may be connected, and subservient to each other; for if it were not for these associations by means of the nerves, the different systems composing the body would be too independent, and although a variety of mechanical operations might be going on it, they would not tend to any useful purpose, but produce the greatest confusion.

Through the superficial cardiac nerve, the pharyngeal plexus becomes more particularly connected with the other nerves of the heart, and from its connection with the ganglia giving branches to the vertebral artery, a communication is kept up between the branches accompanying this artery, and those of the carotids. But indeed, the branches of the sympathetic alone are sufficient for connecting the carotid and vertebral arteries together. The continuation of the ganglia of the grand sympathetic down the spine, and the distribution of branches from them to the aorta,

and several anastomoses of the branches of the two sides: the communications likewise in the abdomen between the different nerves from the ganglia of the grand sympathetic, and their junctions with branches of the par vagum, and other nerves passing on the arteries, form an extensive nervous connexion on the arteries themselves, which is most important, not only for the circulating system and respiration, but also for the animal economy, and has not received that consideration from physiologists which its importance deserves.

The pharyngeal plexus is continued down at the back of the carotid artery, as I have just stated, in the superficialis cordis. This communication connects the nerves of the heart with those forming this plexus, and particularly the superior laryngeal, and thus it produces that due consent between the actions of the heart, and their arteries, which supply so many parts producing the voice, and which is no doubt required in contributing a proper supply of blood.

We are thus enabled to see a most curious

adaptation of power for uniting all the nerves supplying the organs of respiration, and producing so regular an effect, and, at the same time, for connecting the circulation and respiration; and as the organs of respiration are required to vary so much, and to be in a degree of action commensurate with the circulation of the blood, and as the different degrees of distension and action of the arteries stimulate the nerves connected with them according to the state of the circulation, so a better contrivance, or one more adapted to the exigencies of the system, could not have been devised.

Presuming the nerves to be associated and excited for the production of respiration in the manner I have described, it becomes a question how it is managed that they excite the antagonist motions of inspiration and expiration. If the muscles of respiration perform either one act or the other, according to the disposition of their fibres, it is nevertheless difficult to understand how they are both executed with so much alternate regularity. If the phrenic nerves be excited by

the heart, so as to produce the motions of the diaphragm; in the action of the other muscles of inspiration, the ribs may become elevated, so as to extend the branches of the nerves distributed to some of the respiratory muscles in a sufficient degree for stimulating them to action also.

The dorsal nerves pass in such a manner between the ribs, that when these are raised very much in a full inspiration, the nerves passing between the most inferior of them become stretched, and thus stimulated so as to produce contractions of the abdominal muscles, and thus a corresponding expiration is effected.

Another difficulty consists in the want of correspondence between the motions of the chest, and those of the heart. The pulsations of the heart are about four to each act of respiration. So long as the phrenic nerves are stimulated by the action of the heart, they may excite the diaphragm; but it is not, therefore, necessary that the whole diaphragm should contract at every pulsation. It would be departing from the usual disposition of

nature for so large a part as the chest to be moved with so much velocity; and as the muscles must have a sufficient time for moving the parts through a certain space, they may be properly stimulated at every pulsation, and then only kept in a requisite degree of excitement. It might be supposed that there could not be a great consent between the lungs and heart, because the latter contracts so many more times in a minute than the former. Respiration's having been placed under the guidance of the motion of the heart, leads to the accomplishment of all its actions more completely than could have been done by any other means.

It does not seem necessary that a certain number of pulsations is requisite for eliciting particular functions of the brain, but that it requires this general stimulus. In the same way, I conceive, many of the nerves are stimulated by different arteries; and it is for this reason they are placed so much in contact. It happens that a moderate excitement of the arteries increases the actions or functions of the cerebral mass; but, if it be too much

continued, oppresses them. A certain degree of stimulus is necessary, too, for promoting the functions of the nerves; and, in proportion to this, the actions of the parts supplied by them are well or ill performed. What I have mentioned respecting the brain, I mean to adduce in favour of respiration; and because there are four pulsations of the heart to one act of respiration, it is no reason why the phrenic and other respiratory nerves are not excited by them. It would be as easy to conclude that the brain could not perform such varied functions, because it is agitated nearly in the same manner continually.

It is a law of nature that the heart should contract a certain number of times in a given space in man and animals; and, no doubt, the same law imparts similar commands on the diaphragm, by making it contract a proportionate number of times also. Thus the quantity of air inhaled in a given space does not essentially differ, as those, who draw in the most, make fewer inspirations; and the quantity is generally found to vary in each inspiration, according to the size of the chest

and action of the heart in different individuals.

When we make any considerable muscular exertion, even if the will be all the while commanding, there must be an alternation of action in the muscles. I conceive, therefore, that although the heart be always stimulating the phrenic nerves, there may be contractions and relaxations of the diaphragm, according to the laws inherent in the economy of the muscles.

I have stated that the phrenic nerves are stimulated by the movements of the heart, and that they consequently produce the contraction of the diaphragm. It is difficult to prove the correctness of this opinion by direct experiment; and I shall, therefore, endeavour to support it by reference to cases in which diseases and accidents have impeded the free motion of the heart, and thus influenced the organs of respiration. Mr. John Hunter* says, "However, it must be confessed that if the heart stopped for any length of time, respi-

* Treatise on the Blood, &c. p. 150.

ration would also stop; and if I were to take the following case as a proof, it would appear that respiration would not go on without the heart's motion. A gentleman was attacked with a pain in the situation of the pylorus. The pain was such as indicated its seat to be in the nerves of the stomach and its connexions; it was such as he could hardly bear. The other attending symptom was a total stoppage in the action of the heart, and, of course, the face was pale and ghastly. Not the least signs of motion could be felt. In this state he was about three quarters of an hour, and at first, conceiving he must die if he did not breathe, he performed the act of breathing voluntarily. This shows that breathing depends upon the action of the heart; and it also shows that, under certain circumstances, the actions of both may be suspended, and yet death not be the consequence."

Scarpa* relates the following case, and I cannot help attributing the difficulty of

* Tabulæ Neurologicæ, p. 4.

breathing to the impediment, formed by the great quantity of matter in the pericardium, to the proper action of the heart on the phrenic nerves.

"Quidam juvenis, novendecim annorum, post quoddam infortunium, mærore confectus, de cordis dolore et thoracis angustiâ querebatur. Cum prævio horrore in febrem acutam incidit. Pulsus explorabatur durus et celer; urgebat spirandi difficultas; sitis erat intensa cum anxietatibus, inquietudine et dolore cordis perpetuo. Semper cogitabundus noctes ducebat insomnes. Sexto morbi die lypothimiâ prehendebatur, et septimo interiit. Viscera abdominalia, non secus ac pulmones, sana et plane inculpata reperiebantur; sed pericardium puris libram semis continebat."

One of the principal symptoms attending inflammation of the heart, or pericardium, is difficulty of breathing; and it is particularly observed after acute rheumatism, when, on examination, no other parts in the chest are diseased. Dr. Wells has related the case of Miss P.*, who died of rheumatic inflammation

* Transactions of a Society for the Improvement of Medical and Chirurgical Knowledge, vol. iii. p. 398.

of the pericardium. "In the evening she was suddenly seized with extreme difficulty of breathing, and an occasional suspension of breathing; while the breathing was suspended, the pulse either did not beat at all, or beat very slowly."

Some may be inclined to attribute the difficulty of breathing to an extension of the irritation to the diaphragm from contact, or some impediment to the passage of the blood through the heart. But I think if an impartial survey of the pericardium and its connexions with the phrenic nerves be taken, it will be determined that the inclosure of the heart in the inflamed pericardium, and the different effects which must be thereby produced on the phrenic nerves by its pulsation, and particularly when the membrane is no longer placed loosely about it, will reasonably account for the impaired functions of respiration arising from the impediment to the proper action of the heart on the phrenic nerves.

For other cases, as tending to confirm the opinions I have given, I beg to refer to those of wounds of the heart, and of aneurism of the aorta, by which blood has been effused into

the pericardium, and of other diseases of the heart itself.

It will be necessary to make some inquiry respecting the functions of the lungs themselves.

As the lungs are of so complicated a structure, it may become a question whether the branches of the par vagum supply indiscriminately all the parts entering into their composition, and whether they tend to produce any chemical change in the blood itself, besides that effected by the air. I am led to conclude that the nerves terminate almost entirely on the branches of the trachea, and that their specific use is to preserve these in such a state of action as will favour the ingress and egress of the air; for when artificial respiration has been produced after decapitation, changes have been effected in the blood similar to those exhibited during life, and which have at the same time kept up the action of the heart.

As I thought it probable that the distribution of the nerves could be determined with greater precision in a large animal, I

examined the lungs of an ox, and shall, therefore, enter into an examination of them, as far as it may tend to elucidate the anatomy and physiology of them in the human subject,

The trachea of an ox is lined with a membrane, which is fibrous and elastic; the fibres are longitudinal, and give it a muscular appearance, so as to resemble very much the muscular coat of the bladder, covered with its mucous membrane, except that its fibres are much more regular than those of the bladder. It covers the inner surface of the cartilaginous rings nearly through their circumference, and at the posterior part, the transverse muscular apparatus, which extends across from the posterior part of each ring: and I may remark, that the rings are more complete than in the human subject, for the cartilage of each side comes nearly in contact. The cartilaginous rings enter only a certain way into the substance of the lungs, but they are throughout lined with a continuation of the same membrane as that of the trachea, and which has nearly the same appearance.

This membrane is then continued on by itself to form the remaining part of the air tube, and this divides and subdivides to terminate in the small cells; it is partly elastic and partly muscular, so that when the lungs are filled in inspiration, it becomes stretched, and in expiration contracts, or returns to its ordinary state; and thus, with the assistance of the chest, easily expels the air from its interior. The branches of the par vagum follow the branches of the trachea, and therefore give, in a considerable degree, the power of contraction to this membrane. When the par vagum has been divided, immediately after death, the lungs are commonly found distended with air, because they had lost the power of expelling it, and as the air cells are already full, fresh air cannot be admitted into the lungs, for effecting sufficient changes in the blood for the preservation of life.

These observations are the result of many experiments, and I shall relate two of them, as they will afford the best account of the appearances found in the lungs after a division of the par vagum.

EXPERIMENT.

June 16th, 1827, at 1 P.M., I divided the par vagum of each side of the neck in a rabbit of moderate size. He soon after breathed with great difficulty, and died in the night.

The divided extremities of the nerves were separated from each other about half an inch. The lungs were so distended, that they entirely filled the chest, and were purple in patches. The stomach contained food, all of which appeared to be undergoing the process of digestion. Some parsley was eaten very soon before, and some after the experiment, but it was all changed. The stomach was moderately distended, and closely embraced the food.

EXPERIMENT.

June 23, 1827, I cut out a quarter of an inch of the left par vagum in a rabbit. It died at 10 A.M. on the 24th. The left lung was distended, and filled this side of the chest;

the right had purple patches on it, but was collapsed and soft. The liver was very large and full of suppurating tubercles. The stomach was nearly empty.

As the lungs are unable to expel the air, when the par vagum has been divided, it may be a question whether the violent expiratory action of the chest squeezes the distended lung, and bursts some of the cells, and the vessels ramifying on them, and thus produces the purple patches? But the right lung in the last experiment had also purple patches, and it may therefore be doubted, whether the difficulty of breathing had the same effect on this lung; or whether these appearances are to be ascribed to some other cause.

It may be urged that if the air tubes be elastic, the nerves are not necessary for their action; but supposing the nerves impart to them only ordinary sensation, and that they are merely elastic, they may be so overstretched, as to lose the power of contracting sufficiently. But as I conceive they are muscular as well as elastic, and as it cannot be doubted that the arteries have similar properties, and

as we have evidence of the power of the nerves over the actions of the arteries, so we may fairly presume that the air tubes are very much influenced by the branches of the par vagum.

Although the lungs are associated in action with the motions of the chest, yet they have an independent action, and do not expand merely because a vacuum is made by the chest, and contract again because the cavity of the chest is lessened; and as this was, I think, well observed in the following case, I shall briefly relate it.

CASE.

A stout man, above sixty æt. received a compound fracture of the thigh bone, which extended into the knee joint, and which was also complicated with a wound of the posterior tibial artery, fracture of the tibia, and a laceration of the integuments of the leg, and compound fractures of the metatarsal bones; he lost a great quantity of blood,

was in a very faint state, but rallied in some degree after the lapse of twelve hours, he then began to lose ground, and as mortification was beginning in the wound of the thigh, amputation was performed, and although he did not lose any blood, he died very soon after the operation; for the last few minutes, he became insensible, and breathed at longer intervals, until respiration ceased entirely. Although he was completely dead, I yet wished to try whether artificial breathing would avail any thing towards his restoration; and respiration appeared to be as well performed as before he died, by making pressure on the chest, so as to produce complete expiration, when, on taking off my hands, the chest resumed its size, and at the same time the air rushed into the lungs; but on suspending this assistance, and then resuming it after the lapse of a few minutes, although I attempted to re-produce respiration in the same way, yet it was not effected, for the lungs did not appear to fill with fresh air as before. I conceive, therefore, that the vitality of the

lungs was at first so inherent in them, that their actions obeyed those of the chest, but as it diminished, the motions I produced were quite mechanical, and the lungs were no longer capable of acting with them, so as to expel the contained air.

*In a case I published some time since, the patient had taken large quantities of Gout medicines; his digestion had become almost destroyed, and for a short time before death he had great difficulty of breathing; the following appearances were observed on dissection. "Each side of the chest contained about two pints of a dark-coloured fluid. The lungs were not collapsed, but appeared otherwise healthy.

"On tracing the par vagum from the middle of the neck, each nerve was flabby, and much smaller than natural, and felt like nerves removed from a putrid body after having been soaked in water. The branches distributed to the lungs appeared as usual, as did the continuations of the nerves, nearly as

* Observations on some points relating to the Anatomy, Physiology, and Pathology of the Nervous System, p. 11.

far as the termination of the œsophagus, when these were found redder and thicker than usual, and having an unhealthy appearance. The left nerve was smaller than the right."

The appearances of the lungs in this case corresponded with those in the experiments of dividing the par vagum in the rabbits, and were entirely different from those produced by the expansion of the putrefying blood, &c., contained in the lungs after death.

I have stated how the action of the chest is excited for the production of inspiration and expiration; and that the lungs themselves have a power inherent in them for their own motion; and I shall now endeavour to point out, how both the lungs and muscles of the chest are combined in action.

Although there be communications between the grand sympathetic and the par vagum in the neck in man, yet these do not appear sufficiently extensive for effecting the proper association between the lungs and heart, and the muscles of respiration; there is, therefore, another connexion between the grand

sympathetic, and the posterior pulmonary plexus of each side, and also with the cardiac nerves at the back of the aorta. The communications take place by filaments being sent from some of the superior thoracic ganglia on the right side; these communicate with the right posterior pulmonary plexus and then pass across the spine behind the aorta, and become united with branches from some of the thoracic ganglia of the left side, which also communicate with the left posterior pulmonary plexus, and there is then a junction of all these nerves with the cardiac plexus. In most of the mammalia the junction between the grand sympathetic and the par vagum, appears sufficiently great for effecting a proper assimilation; but there is in them also a communication between the first thoracic ganglion and the posterior pulmonary plexus of each side; and the par vagum of each side also communicates before going on the œsophagus. Thus, not only the heart and both lungs are associated in man and the mammalia, but, what is of equal importance, the action of the chest becomes associated

with the lungs also. Some may think, for the production of this general consent between the lungs and the whole chest, that the nerves of the lungs, ought to have communicated with all the ganglia of the grand sympathetic, which are joined to the intercostal nerves. But this, I conceive, is not necessary, because one ganglion communicates with the rest, and can have impressions transmitted through it from several others, with which it communicates. Irritating the Schneiderian membrane, can call all the respiratory muscles into action, through the grand sympathetic, by communicating at one point; and I believe in the same manner, the lungs and chest can be as well associated for every action of respiration.

In birds, there is a communication between the par vagum, and the grand sympathetic, through the superior cervical ganglion, but not in the chest; but a junction takes place between the par vagum of each side, before entering on the œsophagus.

In the goose, there is a connexion between the superior cervical ganglion of the

grand sympathetic, and the par vagum, and there is no other communication between these nerves, so that there is no direct nervous connexion between the lungs and muscles which move the chest. In birds, however, the disposition of the parts is different from that of other animals. The lungs adhere to the posterior part of the chest, and are united to the intercostal nerves, by cellular membrane. It is therefore almost impossible for any action of the lungs to take place without the intercostal nerves being more or less affected by it; and although the connexion between the lungs and chest is very different from that in the mammalia; it is nevertheless suited to their exigencies, and therefore the same nervous communications become unnecessary.

In the turtle, the grand sympathetic, and par vagum, communicate as in many of the mammalia; the ganglion, which proceeds from a large branch of the par vagum, at the bottom of the neck, gives off branches, which encircle freely the different arteries, and are united with the axillary plexus and the

dorsal nerves; and the lungs are thus associated with the action of the muscles; and during the greatest activity of the animal, the grand sympathetic is not only stimulated by the arteries, but a due consent is likewise formed between the nerves of the lungs and those of the anterior extremities. Respiration is performed at very uncertain intervals. It expires and inspires instantaneously. The cavity of the chest must be diminished so that the lungs may be compressed, and the expulsion of the air assisted; for, although the lungs be elastic, I do not think these have a voluntary power of contraction, and therefore some external one is required for its assistance. As respiration is performed at such uncertain intervals, it may be a question whether it take place through the stimulus communicated by the blood-vessels. The arteries are very thickly surrounded by nerves, but, as I have not dissected this animal so thoroughly as to comprehend every thing connected with its respiration, I will not offer any speculations on the subject.

In fishes, the grand sympathetic commu-

nicates with the fifth, and also with the par vagum, and from both these nerves, branches are given to the muscles of the gills themselves, and also to those, which belong to their covering. The grand sympathetic on each side becomes very much connected with the branch returning the blood from the gills to form the aorta, and this connexion can, I conceive, stimulate the nerves of the muscles of the gills so as to produce their action.

In the cod, there is also another branch of the par vagum, which winds round a large artery, returning the blood from the gills, and is distributed to the muscles of the throat.

Nothing can more strikingly illustrate the connexion between the lungs and chest, than the alteration which takes place in the form and capacity of the chest when the functions of either lung have been impeded by the removal of a portion of the par vagum, as was manifested in both of the following experiments.

EXPERIMENT.

1827, June 13th. I removed from a large terrier a portion of the left par vagum, which

measured five-eighths of an inch. For some days he was very unwell; and the principal symptoms he was for a long time troubled with, were sickness, an indistinctness of barking, and loss of flesh, but these gradually and very materially went off. A year after the operation he barked loudly, but not perfectly; he frequently vomited up his food and ate it again, but he was well fed, so that his body was sufficiently fleshy; and he breathed well.

1828, June 14th. At a quarter before five P.M., I divided the right par vagum. A quarter of an hour after the operation he vomited. The conjunctiva of the right eye became more red than that of the left. He had an occasional heaving, something like hiccup.

15. He appeared to have a constant trembling. He drank water, and immediately attempted to vomit. He could not eat; he did not breathe with much difficulty. In the afternoon his breathing was rather short, and he did not appear quite so well as in the morning.

16. He is better, and does not breathe amiss. He will not eat, and always vomits after drinking water.

17. He breathes with great difficulty, and vomits a great quantity of mucus, and does not appear near so well as yesterday.

He continued to vomit throughout the day; his breathing got worse, and he died at half past seven P. M.

EXAMINATION.

There was a remarkable difference in the two sides of the chest. The left side was flat and small; but the right side was enlarged, so as to be much more capacious than the left.

The left par vagum from which the part was removed, was united by apparently new small nerves, and a twig went from the branch of the first cervical, which joins the descending branch of the ninth to the inferior portion.

The right nerve was united by a coagulum of blood. The right lung was not collapsed, and was very purple in patches, and more solid than natural. The left lung was more solid than the right, and much less, and had

the same purple patches as the right. The heart was sound.

The stomach was contracted in the greatest degree. The intestines, and all the other abdominal viscera were healthy, except a few red spots on the mucous membrane of the superior part of the intestines, which had the appearance of ecchymosis.

The left recurrent nerve was much less than the right.

The dog had much fat in different parts of the body, and seemed to have died from want of a proper change in the blood, which was quite black in the aorta.

EXPERIMENT.

June 23d, 1827. I cut out a portion of the right par vagum in a white rabbit, which measured a quarter of an inch after it was removed.

It has hardly been affected by the operation, and has had many litters of young ones, and was fat and healthy in appearance.

1829, February 19th. At a quarter before one, P. M., I cut out a portion of the left par vagum, and removed every nervous twig near the carotid. When the nerve was taken hold of with the forceps, pain was produced. Immediately after the operation, it breathed with difficulty, but with not near so much as when both nerves have been divided at once.

20. At 11 A. M., it breathed with great difficulty.

21. It continued very restless, and breathed with great difficulty the whole of yesterday. It vomited some mucus mixed with a little parsley.

22. It breathes better to day, and very much like a person in apoplexy. It grinds its teeth, and eats very little.

23. It continued better yesterday, and is still better to day. It makes some noise in breathing, but breathes with comparative ease. It ate some parsley this morning.

25. It breathes with more difficulty, and gets very thin, although it eats with a moderate appetite.

26. It breathes with very great difficulty.

27. It was found dead this morning, and was examined about 2 P. M.

The right side of the chest was flat, and the left side was considerably larger than the right. Both lungs were diseased, the upper two-thirds of each contained many tubercles, a few of which were in a state of suppuration; the lower portion of each lung was free from tubercles. There were purple patches on the sound part of each lung. There were many hydatids in the abdomen, but all the other viscera were sound.

The par vagum of the right side had united, and although the bond of union was smaller than the original part, it had the appearance of nerve.

These experiments were made for the purpose of ascertaining whether the new substance formed, when a considerable portion of nerve has been removed, will perform the functions of nerve. In the last experiment I think the animal would have lived if the lungs had been sound, as it survived the last operation much longer than is ever known

when the par vagum of each side has been divided. The experiments show particularly the connexion between the lungs and chest; as there was a diminished capacity of the chest in each of them, corresponding with the want of action in the lungs.

I have stated before, that in man the action of the diaphragm is produced by the motion of the heart, which stimulates the phrenic nerves; that the subclavian arteries are encircled by branches from the last cervical ganglion of the grand sympathetic, which pass over and also underneath them: and that the branches of the grand sympathetic, joining the intercostal nerves, are peculiarly connected with the intercostal arteries, and by this connexion of the nerves and arteries, the parts they supply are made to act in unison with the diaphragm. In all the mammalia, nearly similar nerves and their approximations with the heart and arteries exist. There is, however, a modification in some of them. In the ass, the branches of the inferior cervical ganglion are not placed near the subclavian artery exactly in the same

way as in man, but the first thoracic ganglion is connected more particularly with a large artery, which forms the superior intercostal, and sends very considerable branches between the ribs to the muscles of the back; and the par vagum in the lowest part of the neck, and the first thoracic ganglion of the grand sympathetic, have altogether a peculiarity of position. The connexion also, between the grand sympathetic and many of the intercostal arteries in the ass, is very curious, inasmuch as these arteries become embraced by two branches of the grand sympathetic, as they pass to each intercostal nerve. From the situation of the par vagum with respect to the subclavian artery, and particularly on the right side, it is placed for being acted upon by the motion of the arteries in a greater degree than in man.

The lungs of birds are of a firmer structure than those of the mammalia, and are more or less fixed to the posterior part of the thorax, so that a comparatively slight expansion is produced by inspiration, and the thorax indeed is so constituted, as not to admit of a very extended enlargement. There is not a

muscular diaphragm as in the mammalia, but only a transparent membranous separation from the abdominal viscera, but there are some muscular slips which arise from the ribs, and are inserted into the membrane on the lungs, and by their contraction tend to expand the lungs. The other muscular apparatus for assisting respiration is very limited, and as the lungs are not required to be expanded in the same degree as in the mammalia, we accordingly find not only less powerful muscles, but also a corresponding disposition of the arteries and nerves for putting them in action. Contrary to the distribution of the nerves in man, and some of the mammalia, we have not them so immediately connected with the largest arteries, but with one of inferior size, and which somewhat corresponds with the same in the ass; and thus an action is excited proportionate to the requisite motion of the chest. But the other intercostal arteries pass underneath the prolongation and the branches of the grand sympathetic in a somewhat similar manner, and for the same purposes as in the mammalia.

The vertebral artery in birds passes upwards

as in the mammalia, and a branch of it passes downward, and furnishes the superior intercostal arteries in a similar manner to the subclavian in man; but the divisions pass over, and also underneath, the most inferior or additional portion of the rib, near its attachment to the spine, and then send off branches to the intercostal spaces: the other intercostal arteries are given off from the aorta. The grand sympathetic, in passing down, sends a branch over, and also underneath, each of the additional portions of ribs, and is connected with the arteries in a similar manner, and to answer similar purposes as in the mammalia.

The branches of the grand sympathetic, which are sent up with the vertebral artery in man and the mammalia, in birds form the prolongation of this nerve. I think it not improbable, that for easy flight, it is required that the muscles of the neck should be associated with the respiratory motions, as well as those of the wings, as the act of flying is so particularly depending on a nice adjustment of all the superior parts of the body,

and therefore that this continuation of the grand sympathetic, and its communications with the cervical and intercostal nerves, are principally intended for this purpose.

When a modification of any important actions is found in different animals, we naturally expect that the structure of the organ or part, which is subservient to its production, will be so arranged as to accord with it. Thus, as we have nearly the same effects from respiration in all the mammalia, so we have nearly the same conformation of all the parts which produce it. In birds, the lungs differ in structure from those of the mammalia; and, therefore, the parts subservient to their functions also differ, so as to correspond with the variation in the lungs. In the mammalia, the lungs appear to be very considerably influenced by the motions of the chest. In birds, the apparatus of the chest is much less powerful; but the lungs themselves, on the contrary, have greater contractile powers than in the mammalia. To effect the great and powerful motions of the chest in the mammalia, the branches of the grand

sympathetic are generally connected with the largest arteries. In birds, on the contrary, the connexion is with arteries of an inferior size, and proportionate with the difference of the required motion of the chest.

If the branches of the grand sympathetic, which encircle the subclavian or other arteries in man and the mammalia, do not exist for associating the nerves in respiration, for what purpose were they formed, and why are they so constant? In birds, they do not encompass the subclavian arteries, which are nearly the same as in the mammalia. We may presume, therefore, that the nerves are not placed in this peculiar manner for promoting the circulation in these arteries. In birds, too, we find a different disposition of the thoracic nerves of the grand sympathetic, and also a distribution of arteries calculated for assisting their functions; so that respiration may be excited in a different degree from the mammalia, but nevertheless in a similar manner, and one well fitted for the exigencies of the animal.

When the phrenic nerves have been divided,

respiration can still be performed many hours, sufficiently for the maintenance of life; but if the spinal marrow be divided in the same animal, just above the part from which the intercostal nerves arise, death immediately takes place. If the phrenic nerves have not been divided, but the spinal marrow has been injured just above the origin of the dorsal nerves, respiration will be kept up sufficiently to support life for several days, by means of the diaphragm. Although both these parts, viz. the diaphragm, and the capacity produced by the motion of the ribs, are required for the respiration of the mammalia, in birds one of them suffices. In birds there are only some muscular slips, resembling the diaphragm of the mammalia: and the same assisting power is not required; as the lungs are of a firmer structure, and incapable of the same enlargement, and therefore a corresponding capacity of the chest would have been useless. Respiration in the mammalia, when the phrenic nerves have been divided, is similar to the same process in birds, and

has, indeed, been carried on perpetually as in them; for, in the following case,* the diaphragm was altogether wanting.

"Puer asthmate chronico et frequenti tussi ab incunabulis vexatus, tandem septimo ætatis anno extinguitur.

Cadavere cultro anatomico subjecto; nullum reperiebatur diaphragma; desiderabatur etiam mediastinum. Pulmones vero a solita forma degeneres unicum lobum præbebant."

I shall, in the following pages, make some observations on the facts and opinions of others, brought forward on the subject of respiration.

Fleurens states, that the regulating principle of respiration resides in the medullæ oblongata; and he draws this conclusion from the immediate stop which is put to respiration when this part is divided. He says:†—"Ainsi, une simple section au-dessus

* Lieutaud, tom. ii. p. 100.

† Recherches experimentales sur les Propriétés et les Fonctions du Systême Nerveux dans les Animaux Vertebrés, p. 179.

de la moëlle costale arrête le jeu des côtes; au-dessus de l'origine des nerfs diaphragmatiques, le jeu des côtes et du diaphragme ; à l'origine même de la huitième paire, tous les mouvemens inspiratoires du tronc, à la fois; et, quelques lignes par delà cette origine, elle n'en arrête aucun.

Il n'est donc pas étonnant, qu'en ne supprimant directement que ce point, on les supprime tous, sans toucher à l'origine immédiate d'aucun.

Toutefois, dans ce cas-ci, ce n'est pas précisément eux qu'on supprime ; c'est seulement leur lien et leur premier mobile. Dans le fait ils survivent tous, sinon en acte, du moins en puissance ; une excitation exterieure peut encore les provoquer chacun en particulier ; il n'y a d'éteint que leur simultaneité et leur spontaneité."

If the division of this part of the medulla oblongata had the effect of stopping respiration only, we might, indeed, suppose that its cause was entirely seated there ; but as it likewise destroys the powers of the limbs and the rest of the trunk, we have as good reason for con-

cluding that the regulating principle of the trunk resides there also. I am fully convinced that each nerve has its particular communication with the brain, from which it derives its power; and, as the spinal marrow receives prolongations from the brain, the integrity of which is necessary for the due performance of the functions of the nerves, so on the division or injury of this at any point, the principal functions of the nerves below it, are destroyed.

Le Gallois* says: — "Mais quelle que soit la disposition organique, en vertu de laquelle les phénomènes mécaniques de la respiration dépendent du cerveau, cette dépendance est certaine. Et il est certain encore, que c'est par la moëlle épinière qu'elle s'exerce. Car, comme je l'ai déjà dit, si l'on coupe simplement cette moëlle près l'occiput, l'animal se trouve sensiblement dans le même cas que si on l'en eût coupé la tête. Ce n'est pas du cerveau tout entier que dépend la respiration, mais bien d'un endroit assez circonscrit de la moëlle allongée, lequel est situé á une petite

* Expériences sur le Principe de la Vie, p. 37.

distance du trou occipital et vers l'origine des nerfs de la huitième paire."

I shall introduce the case related by Mr. Lawrence,* as being of the greatest importance, not only as confirming the results of the experiments which I have just quoted, but also as showing, that but a small portion of the human brain is necessary for imparting to the nerves of respiration their requisite power, and this must be sufficient to prove, that the ordinary act of respiration is independent of the sensorium, the will or mind.

"An acephalous child was born on Sunday, and lived till the following Thursday evening. The brain and cranium were deficient, and the basis of the latter was covered by the common integuments, except over the foramen magnum, where there existed a soft tumor, about equal in size to the end of the thumb. The smooth membrane covering this was connected at its circumference to the skin. The child, as is generally the case in such instances, was perfectly formed in all its other parts, and had attained its full size. It

* Medico-Chirurgical Transactions, vol. v. p. 167.

moved briskly at first, but remained quiet afterwards, except when the tumor was pressed, which occasioned general convulsions. It breathed naturally, and was not observed to be deficient in warmth, until its powers declined. I regret, that from a fear of alarming the mother, no attempt was made to see whether it would take the breast; a little food was given to it by the hand. It voided urine twice in the first day, and once a day afterwards: it had three dark-coloured evacuations. The medulla spinalis was continued for about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumor on the basis of the skull. All the nerves, from the fifth to the ninth, were connected to this. The intestines contained a moderate quantity of the usual dark-coloured substance: and there was a little fluid, of the ordinary appearance, in the gall-bladder. Soemmerring and Morgagni have observed that most of these acephalous children are females: and it has been found in many instances that the renal capsules were very small. The present case exemplified both these observations."

Mr. C. Bell* believes that all the respiratory nerves arise from the same track of the brain and the medulla oblongata and spinalis; and it is thus that all the muscles concerned in respiration become associated; but that he felt difficulties on the subject must appear from the following passages:—

"In the act of respiration we see a succession of regular motions, extending to a great part of the animal machinery. We perceive, at one glance, that this is a new species of activity, and that this new energy must be derived from a source different from locomotive powers. Looking to the simultaneous motions of the abdomen, thorax, neck, throat, lips, and nostrils, in breathing, it is obvious, in the first place, that they must be animated by nerves partaking of similar powers; and that these nerves must have a centre somewhere, so that they may be simultaneously and equally excited, and give a uniform impulse to the muscles of respiration."

Again: "It appears, then, that there are

* Exposition of the Nervous System.

four nerves coming out of a track or column of the spinal marrow, from which neither the nerves of sensation, nor of common voluntary motion take their departure. Experiment further proves, that these nerves excite motions dependent on the act of respiration."

"I have been always desirous of stating, that the absolute proofs stop here, and that the rest is hypothesis. I imagine that the same column or track which gives origin to the fourth, seventh, glosso-pharyngeal, par vagum, and spinal accessory nerves, is continued downward along the lateral part of the spinal marrow, and that it affords roots to the spinal nerves, constituting them respiratory nerves, as well as nerves of motion and sensation; and that it especially supplies the roots of the diaphragmatic nerve, and the external respiratory nerve."

"The respiratory system must be exercised under an instinctive and involuntary impulse, as in breathing during sleep and insensibility. But it must, at certain times, be associated into voluntary actions. By foreseeing this difficulty, we shall avoid the

danger of pushing the investigation of the anatomy too far, or of throwing a doubt over important discoveries by attempting too much."

Dr. Philip * says, "The muscles of respiration are, in the strictest sense of the word, muscles of voluntary motion; we can at pleasure interrupt, renew, accelerate, or retard their action; and, if we cannot wholly prevent it, it is for the same reason we cannot prevent the action of the muscles of the arm, when fire is applied to the fingers. The pain occasioned by the interruption of a supply of air to the lungs is greater than can be voluntarily borne. Respiration continues in sleep for the same reason that we turn ourselves in sleep when our posture becomes uneasy." Again: "By a certain sensation, a wish is excited to expand the chest. This is an act of the sensorium. Till this act take place, the nervous, as well as the muscular, power, by which its expansion is effected, is inert. It is in vain that these powers remain, if the power which

* Experimental Inquiry into the Laws of the Vital Functions, p. 207.

calls them into action be lost. Thus the removal of the brain puts a stop to respiration."

Dr. Whytt's views appear to be nearly the same as those of Dr. Philip; he says,* "Respiration differs from most of the other spontaneous motions, in being subject to the power of the will; thus we can at pleasure accelerate, retard, or put an entire stop, for a considerable time, to the motions of the intercostal muscles and diaphragm. But, though respiration thus differs from the proper involuntary motions, yet it does not perfectly agree with those that are voluntary, since it is regularly performed in the time of sleep, and when we are awake, although we be not conscious of it.

† "If it shall be objected that the motion of respiration cannot be owing to the mind, or sentient principle, because it obtains at all times, and is kept up when we are asleep and not conscious of it, equally as when we are awake and attentive; it may be a sufficient

* On the Vital and Involuntary Motions, p. 221.

† The same, p. 225.

answer, to observe, that a variety of actions are performed by the influence of the mind, without our adverting to them in the least. To give but one instance: the eyelids never cease, after short intervals, to move, whether we be sensible of this or not; nay frequently, as when anything threatens the eye, or touches the cornea, they move, whether we will or no; and yet these motions are undoubtedly owing to the mind. Why, therefore, may not respiration be carried on much in the same manner, without our attending to it; especially since we have shown that the difficult passage of the blood through the lungs, and the uneasy sensation thence arising, must at all times influence the mind to continue this action?"

"In time of sleep do we not often swallow the spittle, talk, move our limbs, and entirely change the posture of our bodies? Nay, some persons get out of bed, and traverse about from one room to another. Here, then, are actions certainly performed in sleep, which, nevertheless, must necessarily be ascribed to the action of the mind. Further, in cases where breathing is difficult, when the patients are no

ways conscious of it, nay even in time of sleep, respiration seems to be performed, partly by the assistance of other muscles, besides the proper inspiratory ones, *i. e.* by muscles which commonly are not employed, except in voluntary motion, and whose action, therefore, in such extraordinary cases, must be attributed to the mind alone. On what pretence of reason, therefore, can it be urged, that the motions of the diaphragm and intercostal muscles, since they continue to be performed while we are asleep, are in no ways owing to the mind? If, while a child is asleep, and breathing softly, a thick cloth be laid over its face, it will immediately begin to breathe deeper, or quicker, and will go on to respire in this manner, till, the cloth being removed, the cool air is admitted into the lungs. This, undoubtedly, must arise from the uneasiness which the mind feels from the difficult passage of the blood through the lungs, and the want of proper air; in order to get rid of which inconveniences, it moves the thorax with uncommon force and frequency, whence a greater quantity of air is inspired, and the lungs are more widely dilated. In

an asthma, does not the sense of suffocation excite the mind to redouble the motions of the inspiratory muscles, and are we not sensible of this when awake? In sleep, when we are less conscious of this uneasiness, does not the mind persevere in exerting its influence in the same manner upon these muscles? A strong argument this, that the mind, as a sentient principle, is often affected by what passes in the body, and is, in consequence of this, excited into action, when, in the mean time, we do not advert to any such thing."

It is necessary for the nerves connected with the muscles of respiration to have a proper degree of sensitiveness, otherwise they could not be so well stimulated by the heart and arteries; but I cannot conceive that this sensitive quality is necessary for calling the will into action on ordinary occasions, and in health. I am fully aware that irritating air, inhaled into the lungs, will immediately put the muscular apparatus of respiration in action, and even produce voluntary attempts to counteract their influence; but this does not prove that the will is the cause of, or is necessary for the

act of breathing in health. The will can call the respiratory muscles into action, as was done by Mr. John Hunter* in his own case; but it cannot, therefore, be maintained that the will is acting continually, and commanding the action of the muscles of respiration. The will never commands in healthy sleep, but itself sleeps along with the mind, and almost every sentient part of the body. We must allow that some degree of sensation remains during sleep; but it is not enough to be appreciable by the mind. Impressions can be made on the auditory nerves during sleep, in a similar manner to those of all the other sentient parts; but it must be by a very considerable stimulus; and I conceive the constant state of the sentient extremities of the par vagum in the lungs, &c., and of the branches of the grand sympathetic, is very similar to that of the other nerves of sensation during sleep.

Many functions are performed during sleep; but they are all termed involuntary. The functions of the brain are almost entirely sus-

* Treatise on the Blood, &c., p. 150.

pended, and perhaps these are no more performed than through the stimulus of the blood, and the action of its vessels, and thus there is the same measure of action in it, that is required for the performance of the functions of respiration, which also goes on through the stimulus of the action of the heart, and thus also the lungs are supplied by nerves having a similar capability of perception. All the other nerves, except the par vagum, appear to rest during sleep; but it is nevertheless necessary that they should be in a certain degree of excitement, that perception may be ready in all of them; for if this could not be instantaneously produced, the person might frequently be in danger of being destroyed.

Although I do not allow that the mind, or will, has any thing to do with the production of respiration during sleep, I nevertheless believe that the functions of the brain, or at least those of the medulla oblongata, are required to be sufficiently perfect for affording the nerves a capability of receiving impressions from the heart and blood-vessels. And

this degree of sensitiveness will also, through the junctions with other nerves, admit of such impressions as will produce several modifications of respiration, as when sleep is disturbed by a disordered state of the digestive organs, or any other parts, with which the organs of respiration readily sympathize, and the person may still be so much asleep as to be quite unconscious of any change in his breathing.

Immediately after birth, the action of the heart and arteries excites the first act of respiration, and this takes place as soon as the head has escaped, provided too much pressure has not injured the brain, so as to impede its functions. But when the head has been long compressed in its passage through the pelvis, although immediately after birth the navel string may beat strongly and constantly, respiration may not begin for some time, and then only be performed very feebly, or at very long intervals. The brain appears to have suffered so much from pressure, that its nerves are not properly excitable. After a short time, how-

ever, the excitability of the nerves increases, and these then become obedient to the pulsations of the heart, and respiration is perfect.

THE END.

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